COMBUSTION

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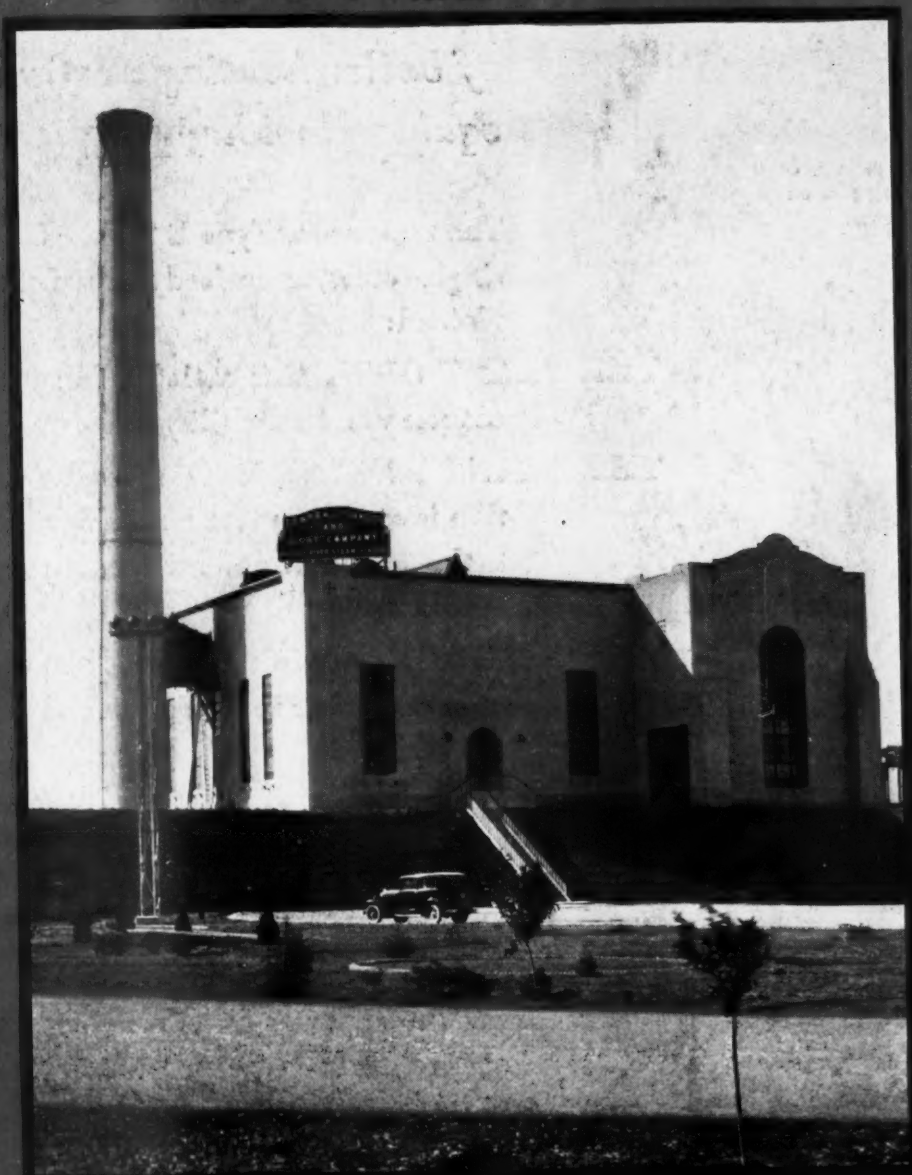

CENTRAL POWER AND LIGHT COMPANY, DEL RIO, TEXAS

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COMBUSTION

VOLUME 3 SEPTEMBER 1931 NUMBER 3

Putting Human Wastes to Work

DR. E. E. BUTTERFIELD

LIFE processes are essentially combustion processes and the wastes therefrom are low grade combustibles. Food digested provides body heat and muscular energy. Food wasted goes to garbage. Undigested and ejected residues of food go to sewage. Extraneous to the wastes from vital processes is the accumulation, paper trash which, when combined with garbage, goes to form mixed refuse. The quantities of these wastes are functions of population and time, and it is perhaps simplest to express them in units of energy contributed, or required, per person per day. Thus, 3,000 B.t.u. are contributed in the garbage-trash mixture, 1,200 B.t.u. in the sewage solids, while 0.0537 kw-hr. is required for sewage treatment by the activated sludge process, all on the basis of "per person per day."

Prevailing practice tolerates the burning of mixed refuse in 250 per cent of excess air at taxpayers' expense and without rebate in steam or power, while, by way of contrast, a privately owned 22,000 kw. station is being operated at high efficiency with hogged fuel of almost identical heating value. In the treatment of sewage, power is used to aerate the liquid sewage and to keep the solids in circulation. Air is supplied for bacterial oxidations also called moist combustion. The chemical efficiency of the oxidation is about 2 per cent, and in terms of combustion air, the excess is 4,900 per cent. Main reliance has been placed on bacterial oxidations for the production of a sanitary sewage effluent. The disposal of the putrescible sewage solids has been a more vexing problem. They have been thickened, filtered and dried for fertilizer, although the revenue from sales has never quite caught up with the cost of production. The gases formed in the putrefaction of the thickened solids have been collected and burned, with a loss, however, of over one-half of the net heating value of the solids. Dr. Karl Imhoff, Chief Engineer of the Ruhrverband, predicted that the thermal energy of these gases would suffice to drive the sewage works, contingent, however, upon more efficient oxidation methods and the resulting reduction in power consumption.

It is not a difficult problem in applied thermodynamics to prove that the net available heat from mixed refuse will balance the power required for sewage treatment, there being available 56,000 B.t.u. net heat of combustion for the production of one kilowatt-hour. Moreover, the sewage solids can be burned with mixed refuse and the gain in the heat balance used for drying garbage or thickened sewage in continuous cycle. This would make the combined disposal of refuse and sewage a combustion process, even to providing power for the treatment of liquid sewage. We are not dealing with visionary schemes. From time immemorial, buffalo-chips and the like have been used for fuel in barren lands. One of the steam generating units supplying a 30,000 kw. set in the Ford British Motor Works will burn London garbage as fuel.

Although the material quantities of combustible human wastes amount to scarcely 3 per cent of our national consumption of commercial fuels, no less than $500,000,000. have been appropriated, authorized, or requested recently for waste disposal projects in a few cities representing less than 10 per cent of the country's population. Amazing have been the engineering achievements in perfecting steam generating units for a receptive public utility market. Given a chance, the same kind of engineering will achieve parallel success with the refuse fuels,—this relates, of course, to combustion engineering *par excellence.*

E. E. Butterfield

Chairman, Committee on Refuse Disposal, American Society of Municipal Engineers.

EDITORIAL

Marine Boiler Practice

UNTIL recently, marine boiler practice lagged far behind stationary practice. Even today, Scotch marine boilers are still in use throughout the merchant marine as well as on many of the largest and fastest passenger liners. Of course, most of these boats were built before the War and their power plants reflect practice at that time.

Within the past few years, however, there has been a pronounced development along the lines of the most modern land practice. This development, as exemplified by the recently built Canadian Pacific liner, Empress of Britain, and the new Cunarder now under construction on the Clyde, is interestingly discussed in David Brownlie's article, "Marine Steam Generation," in this issue.

The power plants of these ships are comparable in every way to our modern central station power plants. Their equipment includes water tube boilers especially designed for the conditions of marine application and operating with relatively high steam pressures and temperatures. Up-to-date instrument equipment and boiler room control systems are employed together with modern combustion methods insuring high overall efficiency.

Oil fuel still seems to find preference on vessels of this type. There are so many factors which collectively make it the ideal fuel for such ships that, under present conditions at least, any advantage of economy offered by coal is greatly outweighed.

For ships, other than large passenger liners, coal is used extensively. Considerable work has been done in the application of mechanical stokers to ship firing, and while a certain measure of success has been attained, relatively little interest on the part of ship owners has been evidenced. Although there is no activity in this direction at the present time, it can still be regarded as having future possibilities since most of the conditions and practices that have handicapped its development could be changed sufficiently to make the use of stokers practical as well as economical. A comprehensive review of this situation was presented in an article "Mechanical Stoking for Ships' Boilers," by S. McEwen, in the March, 1931, issue of COMBUSTION.

Pulverized coal firing aboard ship has also been tried experimentally within the past few years but little real progress has been made. Although this method of firing would appear, from the work thus far done, to be capable of practical application, it seems unlikely that its use will be materially extended unless there is a considerable advance in the price of fuel oil,—an eventuality that is improbable for some years to come.

The present status of marine boiler practice, with respect to the larger vessels, may be briefly summed up as involving the use of water tube boilers of comparatively large size to be operated at substantially higher ratings and steam pressures and temperatures then have heretofore been regarded as good marine practice. Generally speaking, it may also be said to involve the use of oil as fuel and the equipping of marine plants with a full complement of instruments and control systems.

Too Many Engineers Have a "Change it" Complex

ADMITTEDLY progress comes out of original thinking, from the desire to do things differently, presumably in order to do them better,—but why must the engineer who sees for the first time, a drawing of a new design or a layout for a new plant, evidence an irresistible urge to grab his pencil and start changing.

In the field of steam plant equipment this urge, familiar to every designer and equipment salesman, has wasted countless hours of time, delayed construction projects and has cost enormous sums of money, frequently without the gain of a single worthwhile advantage and not infrequently with the actual impairment of the value of the original scheme.

A boiler and furnace layout offers wide latitude to the engineer with the "change it" complex. Despite the fact that it comes to him from the hands of specialists, men whose experience represents years of intimate contact with similar problems, he regards the suggested design as a mere background upon which his ever ready pencil can portray his many personal ideas of improvement.

He would not think of insisting that a manufacturer of turbines or pumps change the design of his product since such equipment is highly standardized and is sold as a unit, but simply because the design of steam generating units is more flexible, he is ever alert to inject into the scheme presented as many of his own ideas as possible.

Fortunately, this attitude is not characteristic of all engineers. In fact, the highly competent and experienced engineer is pretty apt to confine his analysis to the general features of the scheme submitted, checking them as to their general conformity to his requirements and either approving or disapproving accordingly. His attitude and procedure are based on the correct assumption that a reputable manufacturer knows how to design his own equipment and apply it to meet specific conditions. Furthermore, he is unwilling to assume the responsibility of insisting on extensive changes which will probably represent a compromise between his own ideas and those of the manufacturer and which may jeopardize rather than improve the performance of the installation.

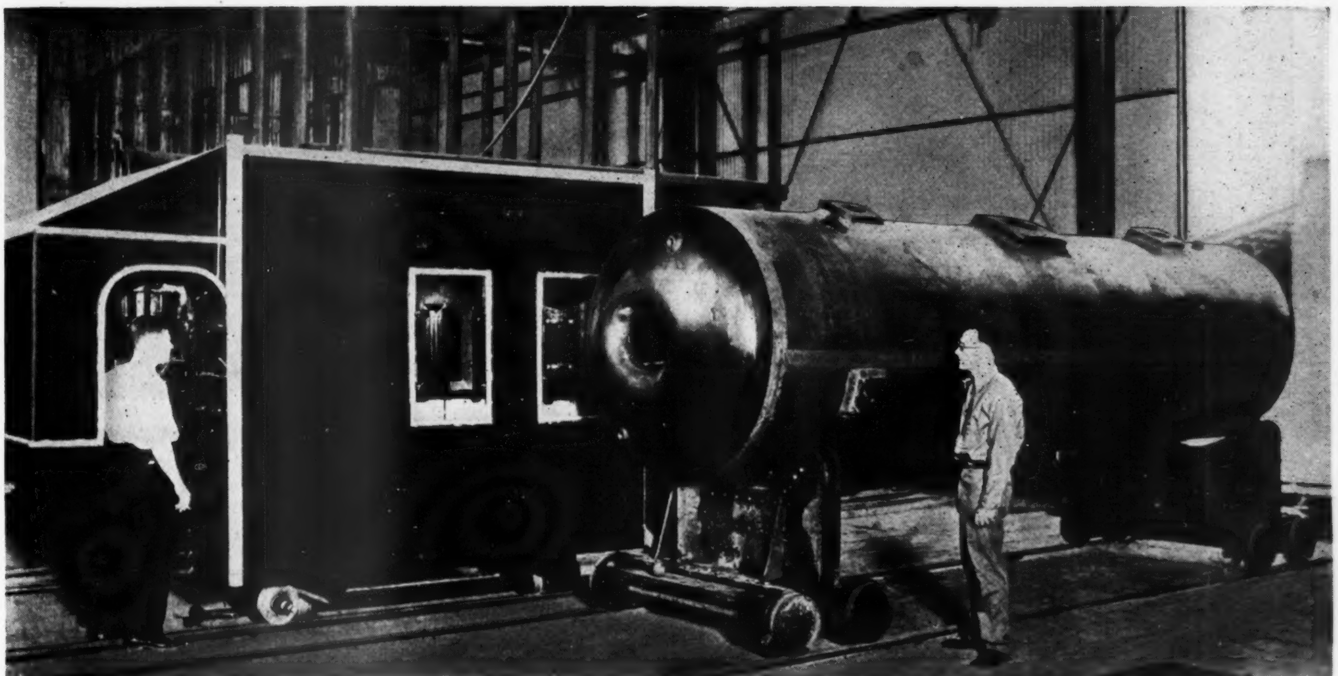

Fig. 1. Exterior view of X-ray car with welded drum in position for radiography.

X-ray Examination of Welded Pressure Vessel Seams

With the recent formulation of the A.S.M.E. Code for welded boiler drums, the technique and methods of testing used in the manufacture of welded drums have taken on an added interest and importance. The author discusses the X-ray method of testing, which method is prescribed in the Code, and also describes an installation of X-ray equipment which is representative of the latest development in this field.

By A. J. MOSES,
Superintendent, Hedges-Walsh-Weidner Co.,
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THAT which has most hindered the application of welding to power boiler fabrication has been the absence of a reliable and practical non-destructive test for such construction.

In an attempt to overcome the objections to welded construction for this class of work, many rigid physical and chemical tests have been devised. But the fact remains that all of these tests, excepting the hydrostatic, must be applied to welding other than that used in the product which is sold. Moreover, the hydrostatic test must approach destruction if it is to furnish any real information as to the ultimate quality of the welded joint. Any properly designed and properly welded pressure vessel should with certainty withstand the hydrostatic test and should not depend upon that test to uncover any flaws or errors in the construction.

It has been argued, that since the plate material for the manufacture of pressure vessels is now accepted on the basis of test results of small samples and on faith, that welded seams should also be so accepted. But plates are forged from heavily cropped ingots thereby eliminating a large proportion of the porocities and harmful segregates. Those defects remaining in the cropped ingot are reduced to a minimum in the rolling operation.

There is no doubt that many processes of fusion welding afford better methods of control which

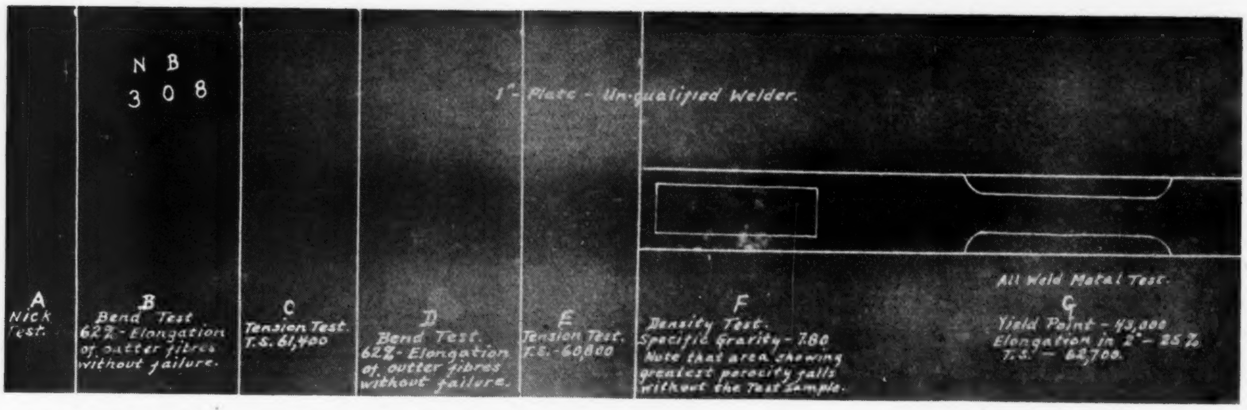

Fig. 2—Radiograph of a 1-inch plate weld made by an inexperienced welder during a qualification trial. This weld contains considerable porocity as shown.

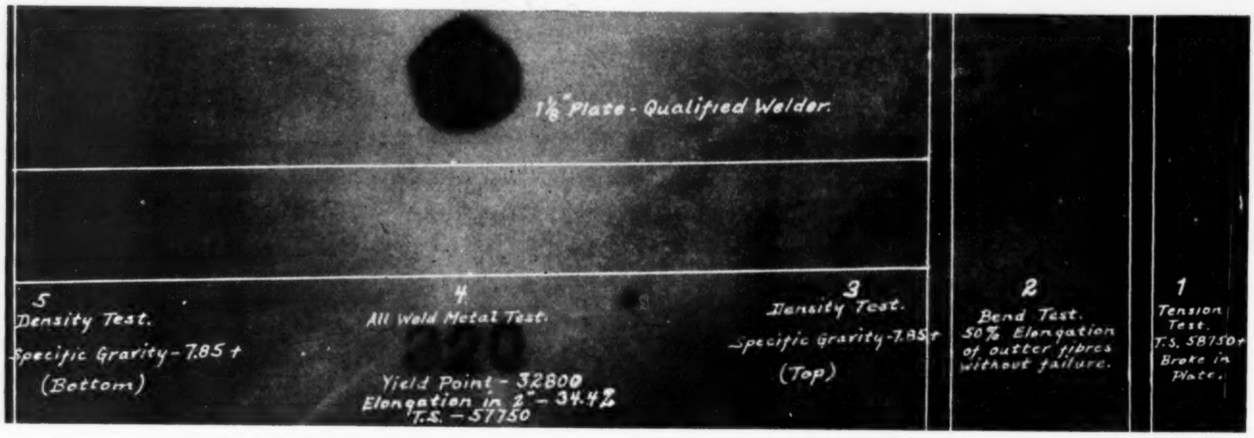

Fig. 3—Radiograph of a 1 ⅛ inch plate weld made by a qualified welder. This sample plate was attached to and welded continuously with a longitudinal weld of a boiler drum.

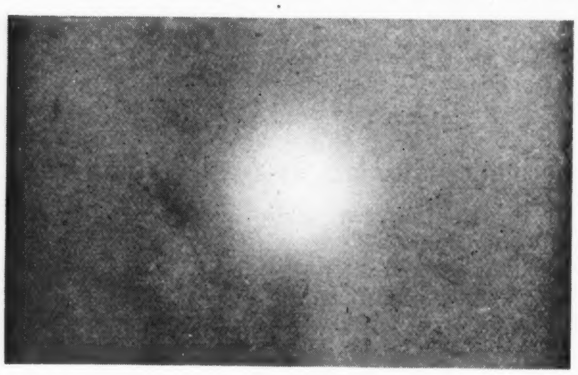

Fig. 4—Radiograph of sample plate prepared as shown in Fig. 8. Incident X-rays normal to surface of plate.

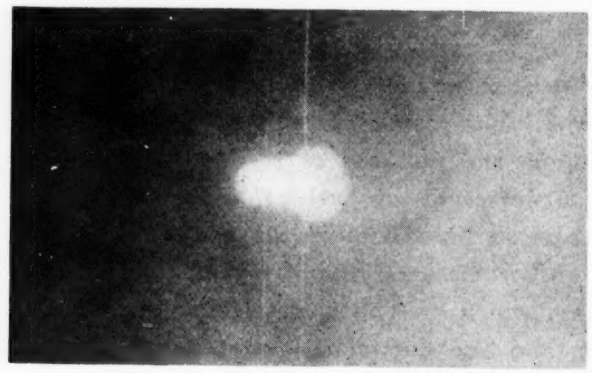

Fig. 5—Radiograph of a sample plate as shown in Fig. 8. Incident X-rays at an angle to surface of plate.

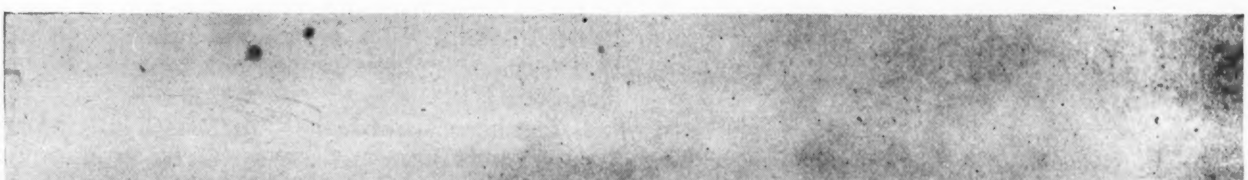

Fig. 6—Stainless steel weld showing lack of fusion at base of welding grooves. Fig. 7 shows section of this welding.

make possible the production of deposited metal far superior in physical and chemical properties to the steel ingots from an open hearth furnace and equal to the refined boiler plate itself. On the other hand it is undeniable that, from its very nature, fusion welding leads to greater variances in some respects than the steel plate manufacturing process.

Therefore, this question is ever present in the honest manufacturer's mind, "Is this welded seam as good as, or better than, the physically tested sample coupons?" Under the old systems of welding, inspecting and testing, such a manufacturer though an expert, could speak with partial assurance concerning only those welds which he personally observed in the making. After testing several thousand welded coupons he may be positive concerning such physical properties as ductility and strength of a sound weld when made under a strict procedure control. But he cannot be positive as to soundness or strict adherence to proper procedure throughout, under any and all conditions. The responsibility of guaranteeing the soundness of the entire welded seams of a large number of pressure vessels is a burden which is too heavy to be placed upon any visual inspection during fabrication.

The use of radiography in the metal industries has increased rapidly during the last decade. X-ray examination of weld seams is not new. But improvements in X-ray equipment within the past few years have furnished the industry with a thoroughly reliable and practical inspection tool for just such work. The X-ray constitutes a homogenity test. As a non-destructive test applied to weld seams, it completes from the point where the physical test of sample coupons leaves off. It furnishes positive assurance as to whether the welding in the seam of the completed vessel is as good as that in the test samples. It will unfailingly detect any appreciable porocities or cracks which may possibly occur in the main seam yet be absent from the test samples. Realizing the immense value of X-ray examination in connection with physical testing of sample specimens, the A.S.M.E. Boiler Code Committee has specified its use in their recent code covering welded construction when applied to pressure vessels and power boilers.

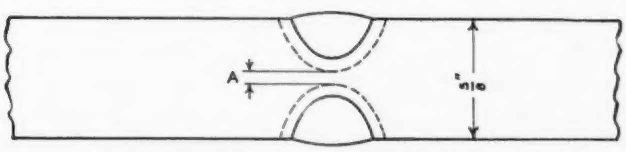

Fig. 7—Cross section of stainless steel weld shown in Fig. 6. "A" is place where lack of fusion occurred.

It is a well known and accepted fact that an X-ray negative will show up porocities in the form of slag or gas inclusions of a depth as small as one or two per cent of the thickness of the plate. Fig. 2 is an X-ray photograph of an experimental weld showing considerable porocity. The notations give the physical test results for the various test coupons. This welded test plate was laid out for the cutting of the various coupons prior to the X-ray examination. The center punching of these layout lines is clearly visible on the negatives. Lines were drawn through these center punch marks on the negative. Fig. 3 is a photograph of a production weld test plate giving physical test results and their location.

Some doubt has been expressed as to the ability of the X-ray to detect small cracks such as shrinkage cracks, or imperfect fusion of adjacent machined surfaces. The X-ray does detect such defects to a remarkable degree and so constitutes an additional check on procedure control as it affects the chemical and physical properties of the deposited metal. During the process of fusion welding, where all the stresses are locked within the weld area, the deposited metal is undergoing a most rigid physical testing. In the welding of plates of appreciable thickness these locked-up stresses are sufficient to cause shrinkage cracks if for any reason the ductility of the deposited metal is impaired. In those welding processes where thin layers of metal are deposited, such shrinkage cracks, should they occur, will rarely if ever remain confined to a single layer of metal. The application of the succeeding layer will either re-weld such cracks or the crack will re-open through the two layers and so on until sufficient ductility is regained. Any cracking that might possibly occur after the completion of the welding would most probably appear on the surface or, at any rate, would leave a fissure easily detected by the X-ray.

Fig. 8—Photograph of prepared plate (X-ray photographs Figs. 4 and 5).

X-ray examination will not reveal laminations normal to the incident X-rays where there is no loss of material, nor will it reveal clearly any cracks which lie at a considerable angle to the incident X-rays. But cracks which are apt to occur in welds will be at an angle practically normal to the surface of the weld and hence easily detected, by the X-ray. Fig. 4 is an X-ray photograph of a prepared sample consisting of two wedge section plugs ground to fit two opposite wedge section grooves in a 1½-in. plate. Fig. 8 is a photograph of this prepared plate. Fig. 4 was taken with the incident X-rays normal to the plate surface. The negative shows very clearly in two shaded strips the loss of metal in the projection of the sides of the plugs. Fig. 5 was taken with the incident rays parallel to one side of each plug. This shows very clearly two of the joints although the fit appears almost perfect.

Fig. 6 shows a more rigid test of X-ray sensitivity. This is a radiograph of a stainless steel weld. Poor penetration has left a lack of fusion along the abutting machined surfaces at the base of the welding grooves. This weld was made by alternating the deposition of metal between the

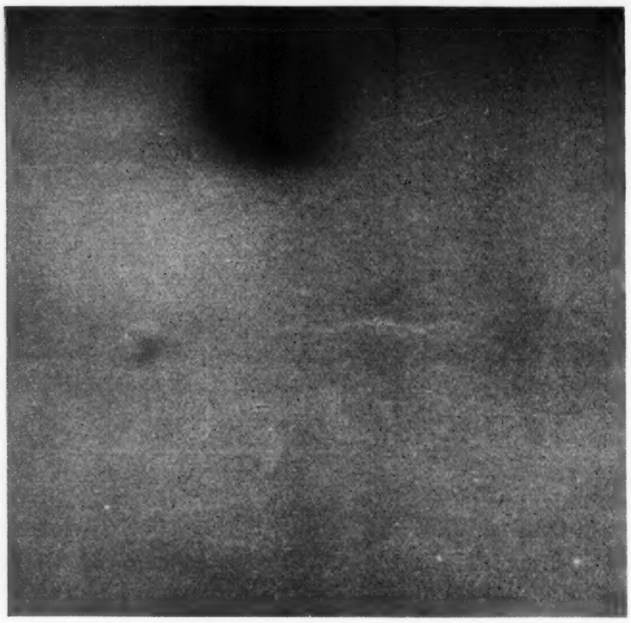

Fig. 9—X-ray photograph showing crack encountered in experimental weld on 2½ inch plate.

two opposite welding grooves. The contraction of the deposited metal has so compressed the machined abuttments at base of grooves that the lack of fusion is not discernible to the naked eye. Fig. 7 shows a section of this weld. Fig. 9 is an X-ray photograph of an actual crack that was encountered in an experimental weld on 2½-in. plate. This crack was chipped out and found to extend

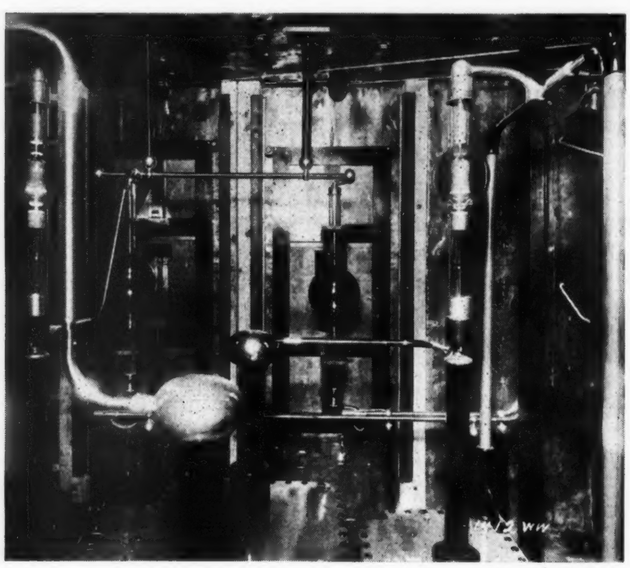

Fig. 10—Interior view of X-ray car showing the two X-ray tubes, Kenetron tube rectifiers and transformers.

from ¾-in. to 1 in. beneath the surface of the weld. Fig. 11 is a radiograph of the same spot after rewelding.

As stated earlier in this article, there has been a considerable improvement in X-ray equipment in recent years. An example of a modern X-ray plant is that installed by the General Electric X-ray Corporation of Chicago for the Hedges-

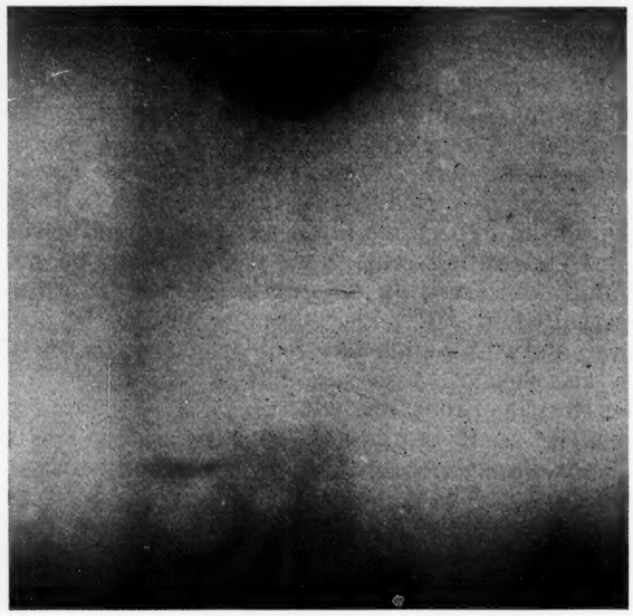

Fig. 11—Radiograph of the plate shown in Fig. 9 after rewelding.

Walsh-Weidner Company, Chattanooga, Tennessee. This installation, which was made and is operated under the supervision of the author, is the highest voltage mobile X-ray equipment yet developed for the radiography of welded pressure vessels. Heretofore, most industrial installations have been of the stationary type, but because of the flexibility required to radiograph all welded seams on all sizes of vessels, the mobile type was best adaptable.

This new equipment, including all high voltage transformers, meters, tubes, etc., is mounted on a truck in a lead-walled container, Fig. 1, 6½ ft. x 6½ ft. x 8 ft., as a protection against both high voltage and X-rays. As the truck operates on a system of tracks 15 in. apart, and with a lateral shift of the container itself of 2 ft., the inspection of any diameter vessel of present dimensions or future consideration can be easily arranged. The vessel to be examined is handled on two trucks mounted with rollers to enable rotation of the vessel when X-raying girth seams. These two trucks also operate on a track paralleling those of the X-ray car.

The side of the container, that faces the pressure vessel to be radiographed, has two small apertures from which the X-rays emerge directed by two small cones that are the only projections on this surface. These cones are removable and can be placed at 90 deg. in order to take care of circumferential radiography. Provision is also made for the use of any length of cone that may be required by projections on the vessels, such as, nozzles, etc.

(*Continued on page 35*)

Selsyn Devices and Their Applications

The accurate and dependable performance of present-day instruments and control equipment has made the operation of modern power plants largely automatic. Within comparatively recent years, there has been marked development in the transmission of important operating factors to recording instruments and meters at remote locations. This development, which has greatly facilitated centralized control, has been chiefly due to the application of Selsyn devices in this field. The author explains the principles of Selsyn operation and describes applications to boiler and combustion control systems in several plants.

By L. U. BAILEY, Electrical Engineer

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EQUIPMENT facilitating the indication and record at a remote point of such factors as liquid level, pressures, temperatures, drafts, vacuums, positions and other factors, has been needed for the efficient and intelligent operation of hydroelectric systems, central stations, gas plants, water works and industrial plants for a number of years. The many advantages of centralized control and of having operating information available at remote points are very apparent in most cases. The development of Selsyns has greatly simplified this problem and offers a rugged, compact and accurate system of transmission, permitting the reproduction at a distance of any motion imparted to the transmitting mechanism in proper manner.

Selsyns have been manufactured for a number of years but have not been used very extensively in connection with metering equipment until recently. Their characteristics, however, make them well adapted to instrument design and complete lines of Selsyn operated devices are now available to give indications or records as well as control from a remote point.

In mechanical construction, Selsyns are miniature, bipolar, rotating-field, three-phase alternators similar in outward appearance to the ordinary small three-phase induction motor and their operation is quite similar to that of synchronous motors. Fig. 1 shows a Selsyn more commonly used in instrument design. The rotor is shuttle wound with a single phase concentrated winding; the stator with a three-circuit distributed Y-connected winding. The rotor winding is connected through slip rings to a single phase alternating current source of excitation and is usually designed to receive its excitation from a 110 volt supply circuit.

A simple system of transmission is illustrated in Fig. 2. The two rotors are excited from a common source and the stator leads are interconnected as shown. When so connected and free to rotate, if one rotor is moved by a mercury sealed bell, a float, damper or any other actuating mechanism, or by an operator, the rotor of the other Selsyn will immediately assume a corresponding position. This reaction is briefly as follows: The single phase current in the rotor circuit will induce voltages in the three legs of the stator circuit which are unstable and vary with the relative position of the rotor. The unequal voltages will cause current to flow in the stator windings, thereby setting up a torque in both rotors. When the rotors of the two

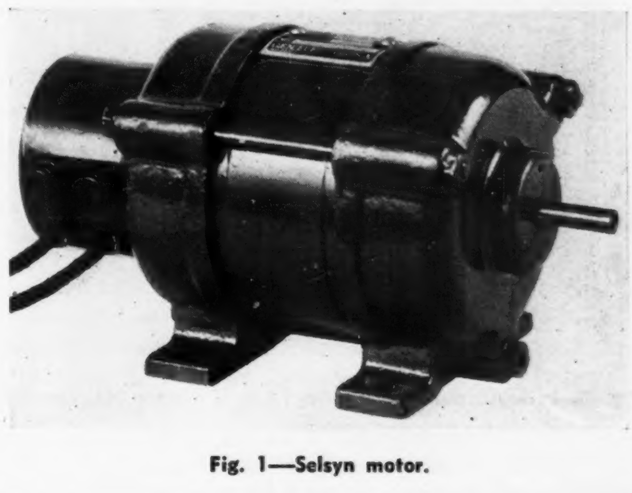

Fig. 1—Selsyn motor.

Selsyns are in agreement, the voltages induced in the one will equal and balance the voltages induced in the other so that no current will flow between the stators or secondary circuit, and the resultant will be zero. However, if the rotor in the receiver is

restrained from assuming the same position as that of the transmitter, the voltages induced in the transmitter and receiver stators will no longer be equal and balanced, and as a result, a current will flow in

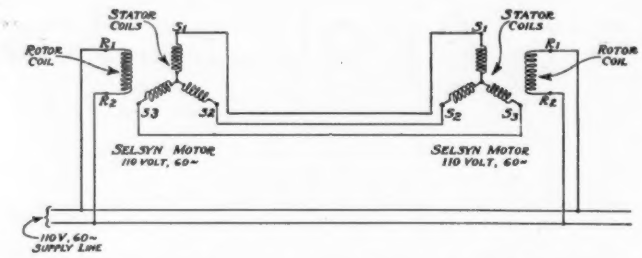

Fig. 2—Wiring diagram and connections of 110 volt 60 cycle Selsyns.

the stator circuit, setting up a torque which tends to bring them into agreement. Consequently, when used in devices for the transmission of position over long distances, the transmitter rotor should be held mechanically by its actuating mechanism and the rotor will, therefore, react against any force which may be restraining the rotor in the receiver and bring it into a corresponding position with the transmitter rotor, thereafter resisting any efforts tending to force it from that position. Even though Selsyns in such a system may be referred to as transmitter and receiver, or generator and motor, the one does not generate electrical power nor does the other transform it into mechanical motion but instead the system merely transmits mechanical motion, and, disregarding friction losses, the mechanical power output of the receiver is exactly the same as the mechanical power input to the transmitter. The Selsyn system is not limited to a single, two-Selsyn circuit as shown in Fig. 2 but instead

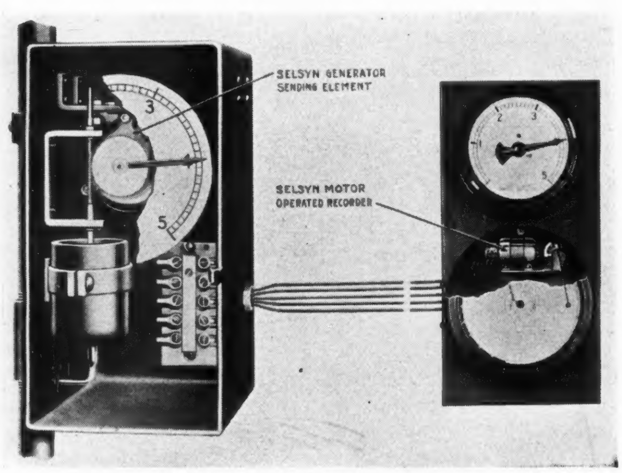

Fig. 3—Pressure transmitter with 12-inch remote indicator and recorder.

more than one receiver may be satisfactorily operated in multiple with a single transmitter.

The applications of Selsyns are too many to be enumerated or classified here, as practically any problem of remote signalling, control or indication offers conditions for suitable application of the mechanisms. A few applications may be mentioned as follows:

For Indicating or Recording the Changes in:

Liquid levels
Pressures
Drafts or vacuums
Temperatures
Rate of flow of steam, gas, air, water or other fluids
Generator rheostat positions
Water wheel and steam turbine governor positions
Lift, swing or bascule bridges
Gas tank heights or pressure
Drum controller position
Elevators and hoists
Gate, valve or damper openings.

For the Remote Control of:

Steam pressure for central station heating systems.
Pumps by liquid level or pressure.
Variable speed motors.
Water wheel governors.
Gates and valves.
Lights in theatres.
Combustion in steam generating units (in connection with other electrically operated or hydraulically operated equipment).
Three element hydraulically operated feed water control.
Ratio and process controls.

The transmitters and receiving instruments available for use in the many applications are numerous and of various designs depending upon the particular conditions to be met. Fig. 3 shows a transmitter and a 12-inch indicator and recorder employing a 12-inch chart which is suitable for indicating and recording at a remote point either pressure, vacuum or liquid level. As shown, the indicator and recorder are mounted on a single panel but this need not be the case and, if desired, the indicator may be located at some point remote to the location of both the transmitter and recorder, or either the indicator or recorder may be omitted entirely from the circuit. This transmitter likewise is very well adapted to automatic pressure control as shown schematically in Fig. 4.

Fig. 4 is a diagrammatic drawing of an installation of automatic pressure control applied to a central district steam heating system and shows how the Selsyn scheme of transmission facilitates the automatic control of a valve in the steam distribution system. In this installation, it is desired to maintain a constant steam pressure in a large office building approximately one mile from the heating plant. The pressure connection for the transmitter is connected to the steam heating line in the office building and the Selsyn transmitter operates the Selsyn receiver in the boiler plant. The receiver, in turn, operates the presser pin of a steam pressure contactor which is provided with an adjustment to permit maintaining any pressure from

1 to 10 lb. in the office building. The master steam pressure contactor in the steam power plant energizes the solenoid operated clutches in a control

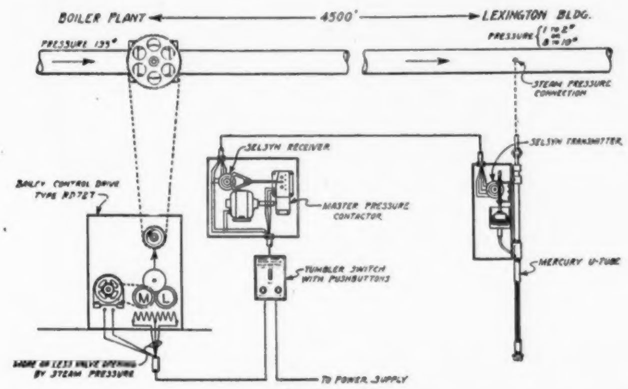

Fig. 4—Automatic pressure control applied to a central district steam heating system.

drive to operate the valve in the steam supply line and automatically maintain the desired pressure at the office building. A tumbler switch with push buttons permits push button operation of the control drive and steam valve when desired.

In the particular application described, the transmitter is used only in connection with automatic control of the steam pressure at the remote point in the distribution system. An additional receiver could be operated from the same transmitter, however, to give either an indication or record of the pressure should such be required or desirable.

The transmitter shown in Fig. 3 and employed in the control system of Fig. 4, consists of a mercury U-tube in which a closed leg is connected to the source of pressure while the other leg terminates in an open reservoir in which a steel float rides on the surface of the mercury. An increase in pressure is balanced by the unequal level of the

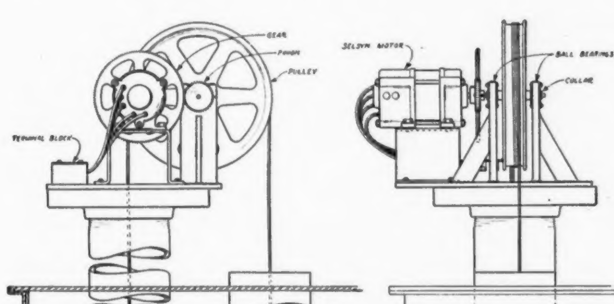

Fig. 5—Float operated type liquid level transmitter.

mercury in the two sides of the U-tube. The displaced mercury rises in the open reservoir and actuates the float which, in turn, rotates the Selsyn generator rotor through a rack and pinion in direct proportion to the change in pressure. This general type of transmitter is suitable for pressures, partial vacuums ranging from a few inches of water up to as high as 30 in. of mercury, and water or liquid level measurement. The design, however, is not usually suitable for pressures in excess of 50 lb. inasmuch as the leg of the U-tube required to give sufficient mercury head to balance the pressure becomes too long and unwieldly for satisfactory installation.

Another type of liquid level transmitter suitable for ranges from a few inches to 100 ft. or higher for transmitting the level of liquids in open tanks, reservoirs, or rivers is shown in Fig. 5. This transmitter consists of a large hollow float resting on the surface of the liquid whose level is to be indicated and connected by a cable to a counterweight so arranged that it will drive the Selsyn generator through gears suitable for the range in level to be indicated. The motion of the float and pulley, which corresponds to the changes in liquid level, is imparted to the rotor of the Selsyn generator through reduction gears so that the rotor turns

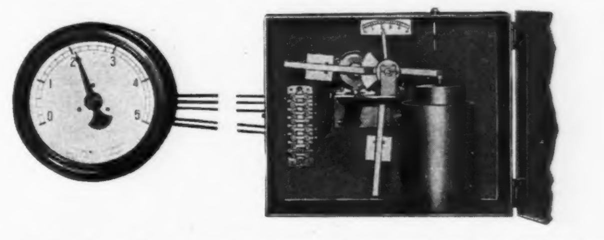

Fig. 6—Draft or low pressure transmitter and remote indicator.

only through the angle over which it is desired to indicate the full range. Either the indicator, recorder or both shown in Fig. 3 could be used in connection with this type of transmitter.

An indicator and transmitter for drafts and low pressures is shown in Fig 6. The generator rotor in this transmitter unit is driven by an oil-sealed bell geared to the Selsyn by means of a gear sector and a pinion on the rotor shaft. The draft connection is made to a stand pipe in the center of the reservoir in the right hand side of the transmitter case. The reservoir is partly filled with oil used to seal the bell which is suspended from a knife edge on a beam supported by a pair of knife edges at its center. The motion of these bells which is proportional to the draft or applied pressure, is imparted to the rotor of the transmitting Selsyn and in turn, to the remote indicator or a recorder if desired. By varying the diameter and length of the bells used, as well as the weight of the pendulum and the height of the oil seal, this same type of mechanism could be used for different ranges of drafts or pressures. Similarly by the addition of a second bell and stand pipe in place of the counter weight at the left end of the bell beam, differential drafts and pressure readings can be transmitted by this unit.

Perhaps one of the most interesting of recent developments in this line of equipment is the hydrau-

lically-operated, power pressure transmitter (Fig. 7) that has been developed by the Bailey Meter Company, Cleveland, Ohio, for operating master

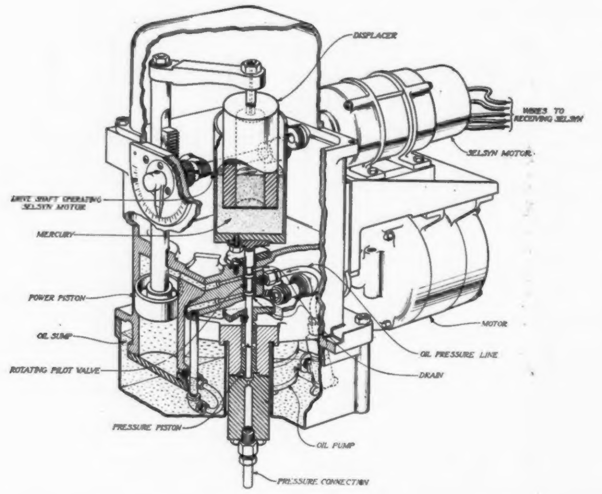

Fig. 7—Power type pressure unit for Selsyn operated indicators and recorders.

pressure indicators and recorders, and particularly for installations where either high or low pressures are desired to be indicated with a very high degree of accuracy over a greatly suppressed and amplified range. This transmitter is suitable for operating any of the indicators or recorders previously described or the large indicator shown in Fig. 8.

It is now possible to obtain practically any size or design of transmitter and receiver required for a particular service. In many cases it is desirable to have, for sake of comparison, two records on a

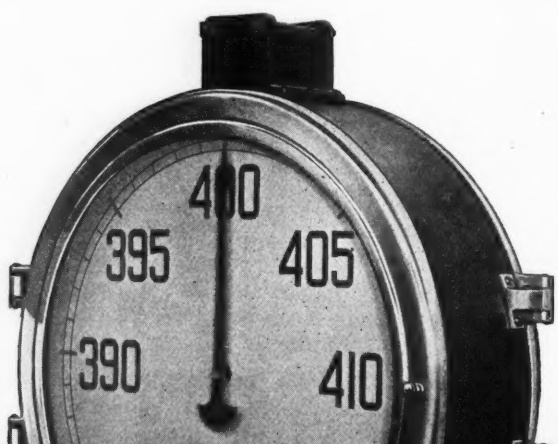

Fig. 8—36-inch Selsyn operated master pressure indicator.

single chart and in view of this fact, two pen recorders are available. Likewise it is sometimes desirable to have several indicators or integrators grouped in a single case and special designs meet these requirements. The installation at the South Amboy Station of the Jersey Central Power and Light Company involving over 100 Selsyns is a very good example of special grouping to meet specific requirements. Fig. 9 shows the panel board at this station, on the front of which is mounted 15 three-pointer indicators while on the back of the same panel is mounted 3 five-grouped integrators of the type shown in Fig. 11.

The present installation in the boiler room of the South Amboy Station consists of three cross-drum boilers designed for a maximum capacity of 275,000 lb. per hour and an operating pressure of 1400

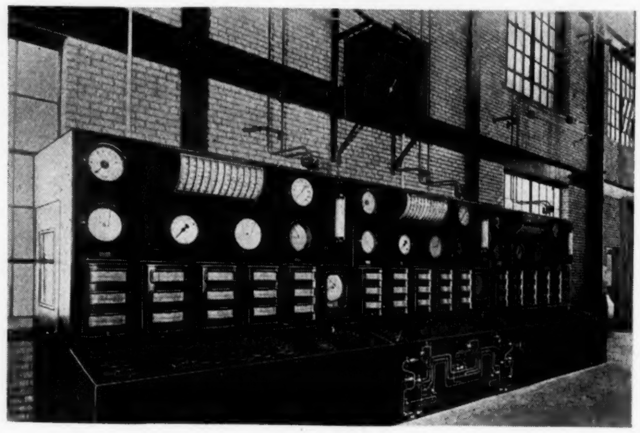

Fig. 9—Operating panel, South Amboy Station, Jersey Central Power & Light Company.

lb. per sq. in. The boilers are fired by pulverized coal, utilizing the unit system and five pulverizing mills supply the coal to each boiler which is equipped with a convection superheater, a desuperheater, live steam and gas reheater, water economizer and an air preheater section. The combustion gases upon leaving the boiler pass through the gas reheater, economizer and then through the air preheater into the stack.

The primary air to each mill, the secondary air to each burner and the quantity of coal fed to each mill is metered. The indications of these three quantities are given on a three scale indicator as shown mounted on the panel in Fig. 9, and as each mill feeds coal to one burner, each of these indicators serves as a guide for one mill and burner unit. Consequently five of the indicators are required for each boiler.

The indicating pointers are all operated by Selsyns. The transmitting Selsyns for the coal indicators are operated by platform scales. Each platform scale, which supports a belt conveyor carrying the coal, is provided with an indicating pointer which shows at all times the quantity of coal passing over the platform on the belt conveyor and the transmitting Selsyn, to which the coal scale indicator is connected electrically, is mechanically connected to this indicating pointer shaft.

The Selsyn transmitters for the primary and secondary air flow indicators are operated by air meters. The differential pressure is obtained by the

use of a steel segment installed in each of the rectangular air ducts. This differential pressure, which varies in a known relation with the rate of air flow is applied to the outside and inside of an oil sealed bell. In order to compensate for variations in temperature of the primary and secondary air, these meters have been constructed so that the consequent change in specific volume is automatically compensated for and the meters correctly indicate the quantity of air regardless of temperature. The air meters with temperature compensators and Selsyn transmitters are as shown in Fig. 10.

Since it is desirable to have a record of the total quantity of coal fed to each mill, a coal feed integrator is provided to show the total weight over any period of time on a four dial counter. These integrators are likewise operated remotely by the same Selsyn transmitters on the coal scales as are used to operate the coal feed indicators. The coal feed integrators are grouped in units of five installed in cases as shown in Fig. 11 and mounted on the back of the operating panel board shown as Fig. 9. One of the five unit integrators is installed on each boiler and the total of all five integrators for any period represents the total quantity of coal fed to that boiler.

In all of the applications previously mentioned, the desired results are obtained by maintaining a fixed or stationary position for the Selsyn stator and frame. In some installations, such as in synchronizing two or more machines, it may be desirable to rotate either the rotor or stator, or both, of the Selsyn transmitter or receiver. On a recent installation in a large midwestern power plant, it was found necessary to synchronize a number of control drives and the scheme of employing a movable stator as well as rotor assisted nicely in the solution of the problem.

In this installation, there are four forced draft dampers and four induced draft dampers to be controlled on each boiler and since they are located at a considerable distance from each other, it was necessary to use two control drives for the induced draft and two for the forced draft dampers. Although both drives in each case operate in parallel and receive electric impulses for operation from the same source, there was some possibility that under certain conditions, they might get out of position and hence not keep all of the dampers together. To prevent this, each pair of control drives is equipped with synchronizing devices consisting chiefly of Selsyns and Selsyn operated equipment. In one drive of each pair is installed a Sel-

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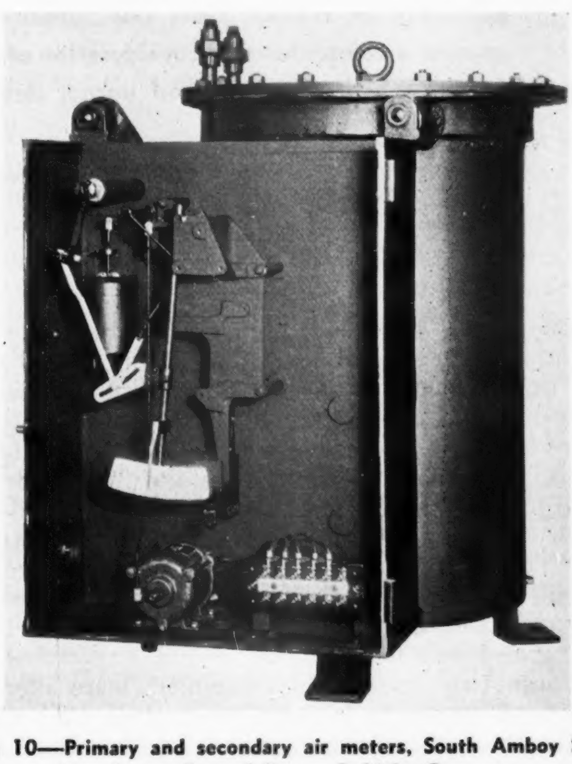

Fig. 10—Primary and secondary air meters, South Amboy Station, Jersey Central Power & Light Company.

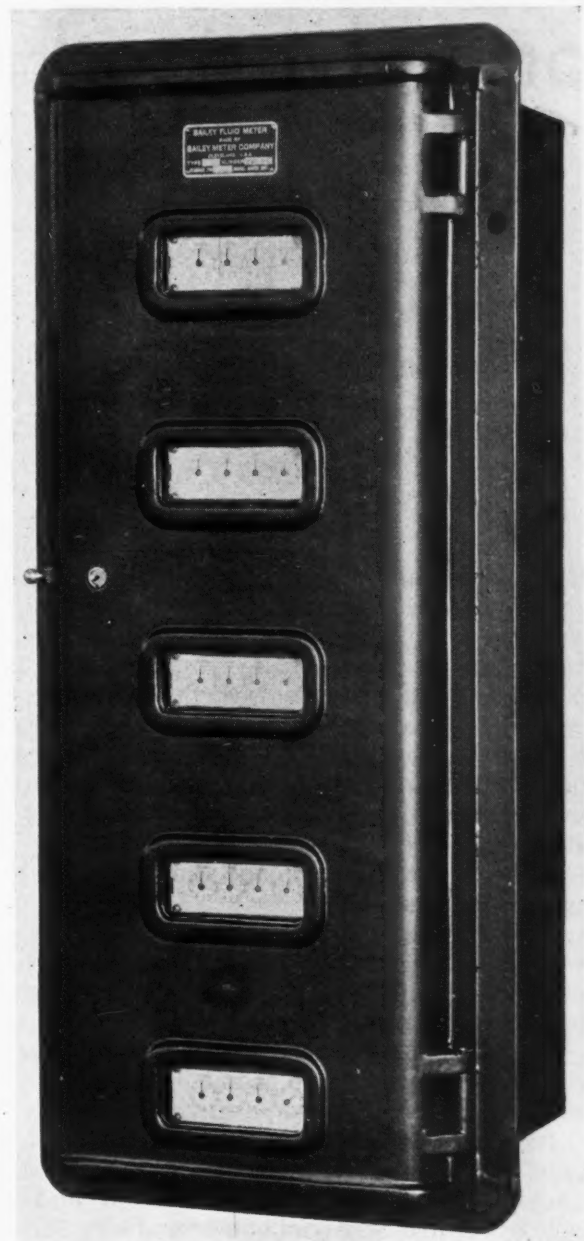

Fig. 11—Coal feed integrators, South Amboy Station, Jersey Central Power & Light Company.

Design and Selection of Burners for Pulverized Fuel, Oil and Gas

PART I

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New York

This is a subject of considerable importance which up to the present has not been dealt with comprehensively in the technical press. This article, written by a specialist in burner design, should therefore, be of great value to the many engineers interested in the subject . . . In Part I, the author points out that burners cannot be considered as independent units. Their performance is so affected by other factors, such as fuel characteristics, furnace design and construction, operating conditions, etc., that the design and selection of burners should be largely influenced by thorough and competent consideration of these factors. The article then classifies burners, first, broadly as to type and then according to application, the latter classification being made on the basis of boiler size and rating. Under the second classification the application of the various types of burners and methods of firing are discussed in detail . . . . In Part II, to be published in a later issue, the author will present a comprehensive consideration of the factors which underlie good burner design.

THERE are many types of burners used for oil, gas and pulverized coal. Most manufacturers make several radically different types, yet the results obtained appear quite comparable. This variety may seem unnecessary to the casual observer, unless it is realized that a burner does not function as a separate unit. Its operation is dependent not only on the nature of the fuel, but also on the characteristics of the preparation equipment, of the furnace, and of the heat recovery apparatus. The size of the boiler, size of plant and nature of load are also important factors.

A few years ago the designs of burners for gas of various kinds, oil and pulverized fuel, had little in common except their simplicity. In the small installations then in use it was not difficult to mix the fuel and air. Furnace walls were always of brick, which absorbed and radiated enough heat to maintain ignition in the non-turbulent, low velocity, fuel streams which were used. Most of the installations using these fuels were industrial furnaces where incomplete combustion and the emission of smoke were not considered very serious matters. Where flame conditions were poor they could usually be improved by using high excess air or by installing refractory baffles in the furnace for flames to impinge upon, or by exposing only part of the lowest boiler tubes to the furnace. Inventors patented many improvements to burners, but had little opportunity to develop them because requirements were not exacting and fuel was cheap.

Two major developments changed this condition for burners used under boilers. The first of these occurred in the marine field with the advent of oil. Burners were needed which would give smokeless combustion, with low excess air, at very high combustion rates. Forced draft was acceptable to operators. This gave the designer positive control of combustion air, and permitted high velocities, with turbulence. There was a market for large numbers of standardized burners. Burners were so important that considerable money could be spent for development, and good, high duty burners for oil resulted. The second development was in the public utility field. Loads were rapidly increasing, power plants were interconnected, central stations were built for base loads, and large units could be used. Plant design was in a state of flux, with the field for pulverized fuel, forced draft, preheated air, high efficiency and high ratings advancing rapidly. This created a demand for larger and more efficient pulverized fuel burners. Several types of burners were being developed, mostly for vertical firing and long flames.

These two lines of development were merged when oil began to be used extensively in central stations. The oil burners which had become highly developed in marine work, were seen to be suit-

able, with slight alterations, for pulverized fuel so horizontal turbulent firing became more general than vertical firing. Vertical firing itself was then made more turbulent and two new arrangements ("Opposed" and "Tangential") were developed to give prolonged turbulence in large furnaces.

More recently there has been considerable increase in the use of blast furnace, coke oven, and natural gas under power boilers. The developments for oil and coal are being applied for gas, (some burners can take care of all three fuels) so burners for the three classes of fuels will be considered more or less simultaneously in this discussion.

Burners for industrial furnaces have so far had an entirely different development. The operating conditions are different. Units are universally small. Efficiency is less important than flame shape and temperature. In general the older forms of burners are still in use. Local conditions are in each case so important that general rules regarding industrial burners have not as yet been well established, so they will not be further discussed here. This article will be limited to the newer forms of burners developed for power boilers.

In the following discussion, burners for power boilers will first be classified in a general way, then their application to various types of installations will be reviewed.

General Classification of Burners

Burners have been designed in so many different ways that no one system of classification suffices for all features involved. For a very broad classification they may be identified as either "straight shot" or "turbulent." The former are generally the simplest, consisting essentially of one or more pipes from each of which a jet of fuel or air is projected directly into the furnace. Usually they give long, non-turbulent flames, but in some cases several burners are so arranged in a furnace that turbulence is obtained by the interaction of their jets. The other group, "turbulent" burners, includes all designs which have irregularly shaped nozzles, or which are provided with baffles or distributors or a number of nozzles, arranged to whirl, spread, or impinge a number of fuel and air streams to make them enter the furnace in a thoroughly mixed and agitated condition. Some "straight shot" designs have been made turbulent with very minor changes, and some turbulent designs do not mix or agitate very thoroughly, so this system of classification is very loose.

Many burners have been specially designed for one grade of fuel, for natural or forced draft, for cold or preheated air, or for specific locations within furnaces, but the special features involved are minor and may be changed to suit a different application. The most satisfactory system of classification, for use in studying burner design, is to group burners according to the way fuel and controlled air are admitted into the furnace. One such system will be illustrated in Part 2 of this article.

In this discussion there is a distinction between "controlled air" and "total air." The former is that portion of the total air which enters the furnace through ports. The rest is leakage through furnace walls, which may be included in "combustion air," or through boiler, economizer and air heater settings or breechings which air is unavailable for combustion. This leakage cannot be overlooked. It will be discussed in detail later.

The controlled air may be "primary air" accompanying the fuel, "secondary air," introduced directly into the burner or furnace, or "tertiary air," added to primary air *at* the burner in types with which the secondary air is not admitted through the burner. Any of these may come directly from the room, or from an air heater, or hollow furnace walls, or storage mill vent. Primary air may also come directly from mills. Primary air is always under fan pressure of 1 to 30 in. Secondary and tertiary air may be induced by furnace drafts up to 0.5 in. (higher drafts cause too much leakage), or be forced by 0.5 to 6.0 in. pressure at the burner (higher pressures waste power).

There are four arrangements used in the installation of burners. "Horizontal firing" is shown in Figs. 1, 2, and 3. "Vertical firing" is shown in Figs. 6, 7 and 8. "Opposed firing" is shown in Figs. 4 and 9. "Tangential Firing" is shown in Fig. 5. "Bottom firing" (vertically upward from the bottom of the furnace) has been tried, but does not find wide favor at present. Figs. 1, 2 and 6 represent only "straight shot," natural draft, non-turbulent designs. Figs. 3 and 4 represent either that kind of design, or forced draft, turbulent designs with either "bushy" or "conical" flames. Figs. 5, 7, 8 and 9 represent only forced draft, turbulent designs with either "straight shot" or "bushy" flames.

Combinations of horizontal and vertical firing are no longer used except for handling two kinds of fuel, as pulverized fuel and blast furnace gas. Auxiliary burners, for emergency fuels or for control of superheat, are, however, still used in a variety of locations.

Each arrangement of burners has advantages for certain types of installations. In many cases these advantages clearly dictate one particular arrangement but for the average installation there has been continued change of opinion, depending on new developments in one system of firing or another.

TABLE I

1. Small boilers—200 to 600 hp. maximum output.
2. Medium size boilers installed for low ratings—600 to 2000 hp. maximum output.
3. Medium size boilers installed for high ratings—1000 to 5000 hp. maximum output.
4. Large boilers—5000 to 20,000 or more hp. maximum output.
5. Double ended boilers—usually large—10,000 or more hp. maximum output.

The selection of burners depends chiefly on the size of the unit. The different types of installations fall rather naturally into the five groups which are given in Table I. The first two groups will be considered separately, then the last three

"high rating" groups will be considered together, with separate discussions of horizontal, vertical, and tangential arrangements.

Burners for Small Boilers

Small boilers are almost universally fired by natural draft horizontal burners when pulverized fuel, oil or gas is used. Their furnace walls are not high so compressive loads in the walls are safe for refractories. Moreover all parts of the walls are close enough to the boiler to be somewhat cooled by it, so solid brick walls are satisfactory. Water-cooled walls are more expensive (per square foot) for small areas than for large ones, and the expense is not justified. Air-cooled floors are inexpensive, and are desirable, particularly with pulverized fuel. If the floor does not heat air enough to dry the coal, partially air-cooled walls should also be used. In a small furnace, the minimum width and depth which will prevent erosion of walls by flame, and the minimum height which will permit complete combustion before gases enter the boiler, result in a furnace volume which gives low combustion rates. Small quantities of fuel are easy to mix with air. Operating ranges are usually narrow.

The above factors combine to make unnecessary the use of forced draft equipment or air heaters on the usual job, but in some cases the expense of forced draft equipment without preheaters on small boiler units is justified. Some of these cases are:

(1) Where provision for high emergency peaks is needed.
(2) Where existing stacks give insufficient draft for new operating conditions.
(3) Where air-cooled walls are so arranged that natural ventilation through them is unreliable, especially in the case of battery walls.
(4) Where any of the furnace dimensions under existing boilers are limited, so long flames or low combustion rates cannot be obtained.
(5) Where automatic control is used.
(6) Where a smoke ordinance is strictly enforced.
(7) Where forced draft equipment for stokers is already in place.
(8) Where burners are supplementing grates or stokers for the burning of waste fuels or coal (drafts are not sufficiently stable in such furnaces to induce a uniform flow of air through burners.)

The use of low combustion rates, narrow operating ranges, natural draft, and small quantities of fuel and air, under small boilers, permits the use of simple burners. The entire fuel burning equipment must be simple, cheap and easy to operate if competition from the smaller, standardized sizes of stokers is to be met. For pulverized fuel a single direct fired, natural draft, horizontal burner, with 2/3 to 2 sq. ft. of furnace opening should be used as in Figs. 2 or 3.

For burning oil, two steam atomizing burners or two or three mechanical atomizing burners should be used, so fire will not be lost when atomizers are removed for cleaning. Oil is easily distributed; the number of burners is not limited by preparation equipment (as in the case of pulverized fuel); small oil burners are standardized and cheap; so the use of several burners is not a handicap. For the smallest units steam atomizing, flat flame burners, with checkerwork furnace floors (Fig. 1) are best. They are particularly suited to temporary oil burning installations in stoker-fired furnaces where the checkerwork may be laid directly on the stoker. Whenever the stoker is to be used, the checkerwork can be quickly fed to the ash pit. This arrangement cannot be used if any pulverized fuel is to be fired, because ash would fill the ports. It is also limited to low combustion rates. Where medium combustion rates, or where mechanical atomizers must be used, horizontal natural draft burners should be installed as in Fig. 3.

Burners for natural or coke oven gas are nearly always also arranged for firing oil because the gas supply is usually unreliable. For this reason the above discussion on oil burners applies also to natural gas burners. Some plants provide for both oil and gas as standby to pulverized fuel, or vice versa, but if long time contracts for oil or gas may be made at rates competitive with coal, burners designed only for these fuels should be used, even though pulverized fuel is a future possibility. Later when pulverizing equipment is installed, it will be a comparatively simple matter to rebuild the front wall for new burners. Designs for pulverized fuel are developing rapidly, and this procedure will provide the latest design of equipment when required. Of course, the furnace must originally be made suitable for pulverized fuel in all such installations.

If the supply of oil or gas is unreliable, or insufficient, so pulverizing equipment for coal must be bought, or if oil or gas are only auxiliary to coal, or a future possibility, the burners should be designed primarily for pulverized fuel. Provision for combined firing is easily made in most pulverized fuel burners, even after they have been installed. If oil is to be used irregularly, a single pulverized fuel burner may be used, and provided with one steam atomizing oil nozzle. If oil is to be used at all regularly there must be two or three atomizers in operation, as on a straight oil fired furnace. The installation of extra pulverized fuel burners and distribution equipment, in order to have two or three combination burners, runs up the cost. Small burners for oil alone or oil and natural gas, are cheaper than combination coal burners of the same size. The extra cost is minimized if one of the arrangements shown in Figs. 10 or 11 is used. The arrangement in Fig. 11 is not advisable unless the oil burners in the back wall are to operate continuously or be bricked up, because ash accumulation on the back wall may plug these burners, or the flame may overheat them.

HORIZONTAL FIRING

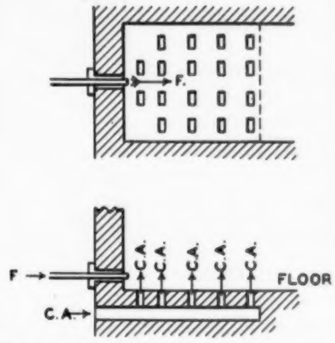


Fig. 1—For oil and rarely natural gas—natural draft, very small boilers.

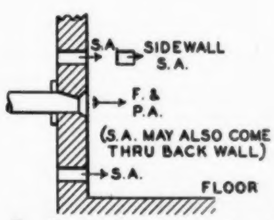


Fig. 2—For pulverized fuel and rarely natural gas — natural draft, very small boilers.

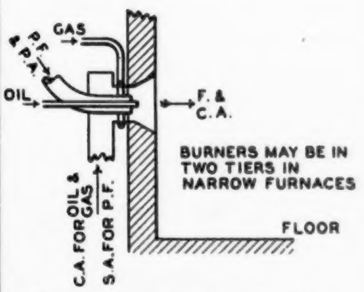


Fig. 3—Suitable for all fuels—natural draft, small boilers; forced draft, medium or large boilers.

KEY TO SYMBOLS—

(Figs. 1 to 12)

P.F.—Pulverized fuel

B.F. Gas—Blast furnace gas

F—Fuel entering furnace along arrow→

C.A.—Controlled air

P.A.—Primary air

S.A.—Secondary air

T.A.—Tertiary air

(C.A. = P.A. + T.A. + S.A.)

TANGENTIAL FIRING

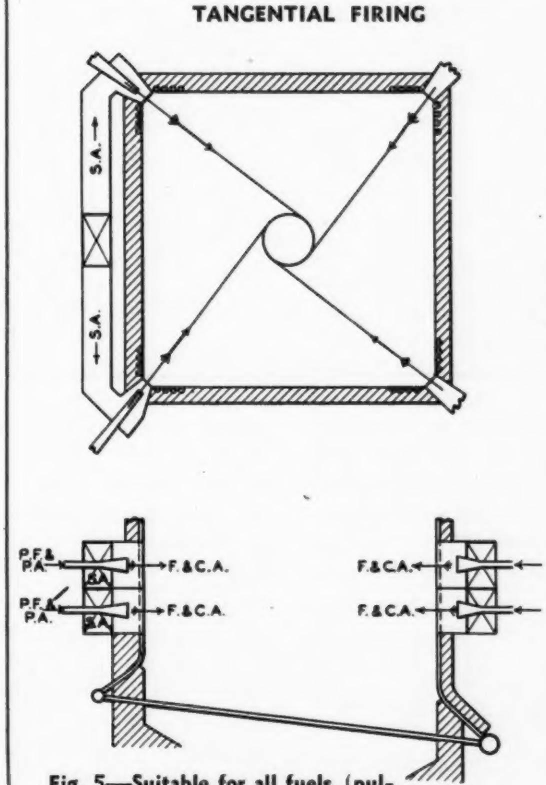


Fig. 5—Suitable for all fuels (pulverized fuel application shown)—forced draft, medium or large boilers.

VERTICAL FIRING

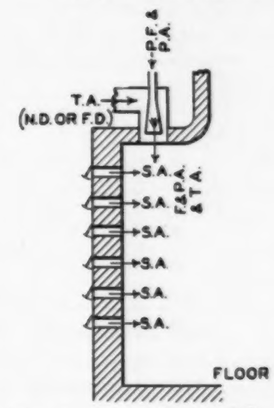


Fig. 6—For pulverized fuel (oil or gas only auxiliary)—natural draft, small boilers.

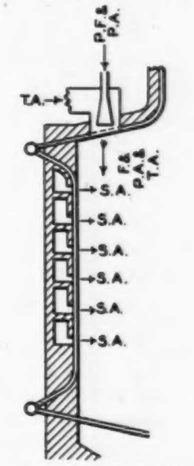


Fig. 7—For pulverized fuel (oil or gas only auxiliary)—forced draft, medium or large boilers.

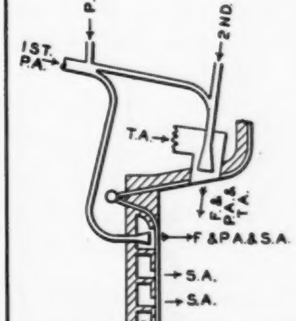


Fig. 8—For pulverized fuel with auxiliary—forced draft large boilers.

OPPOSED HORIZONTAL FIRING

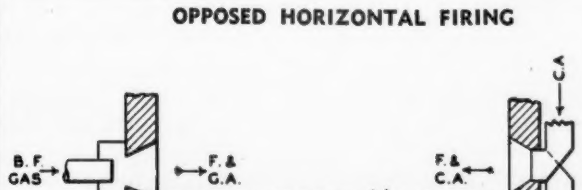


Fig. 4—Suitable for all fuels—forced draft, large boilers.

OPPOSED VERTICAL FIRING

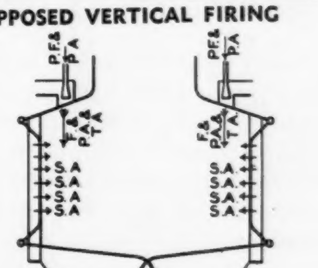
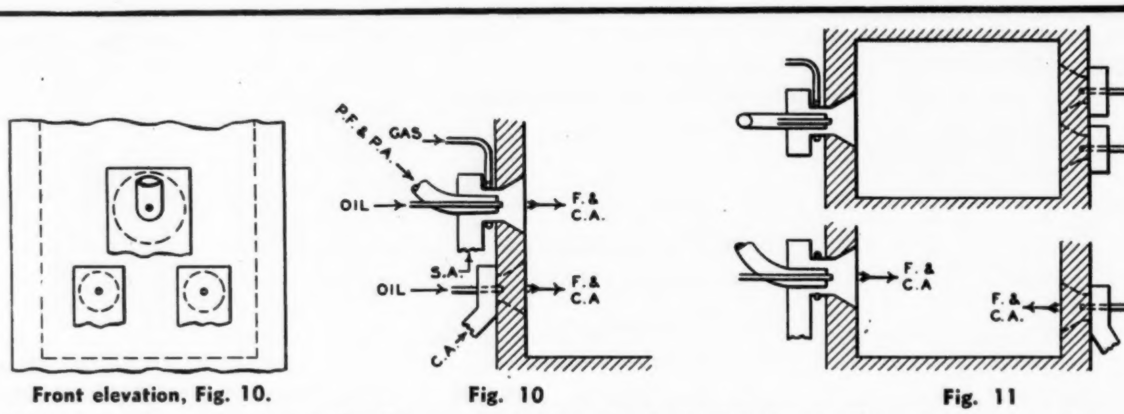


Fig. 9—For pulverized fuel or waste oils—very large boilers.



Front elevation, Fig. 10. Fig. 10 Fig. 11

Figs. 10 and 11 show arrangements for the combined firing of pulverized fuel and oil, or oil and gas, under small boilers. (One combination burner for full load on pulverized fuel and 1/3 to ½ full load on oil, with two separate oil burners each for 1/3 of full load.)

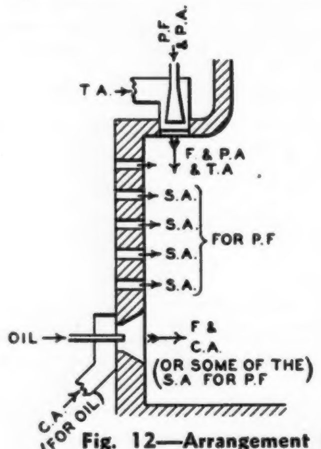


Fig. 12—Arrangement for combined firing of oil and pulverized fuel when vertical firing is used. Either set of burners may be for either natural or forced draft.

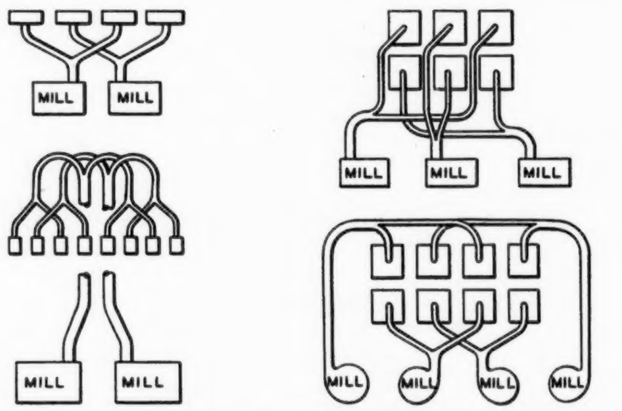


Fig. 13—Diagram showing four arrangements of crossed feed pipes.

For blast furnace gas one horizontal turbulent burner of special design for this fuel is used on a small boiler. With most installations the supply of gas is at times insufficient (due to high steam demand, idle blast furnaces, or slides in a blast furnace) so provision for auxiliary fuel must be made. Some blast furnace gas burners may have oil or tar atomizers or pulverized fuel or coke oven gas nozzles. The multiple mixing type of gas burner in most common use is not suited to this, necessitating separate burners for auxiliary fuel.

Burners for Medium Size, Low Rating, Boilers

Medium size boilers may be divided into two groups, according to requirements for combustion apparatus: (1) boilers intended to operate up to about 200 per cent of rating for which first cost is minimized by elimination of auxiliaries and (2) boilers intended to operate up to 300 per cent or more for which maximum efficiency is obtained by the complete application of heat recovery apparatus and equipment for turbulent firing.

For the first group refinements such as forced draft, air preheaters, fully water-cooled furnaces and perhaps automatic control, soot blowers and wide range combustion equipment are not necessary. Combustion rates are usually somewhat higher than for small boilers because increased size results in higher steaming capacity per foot of furnace width and depth. Wall construction may be similar to that for small boilers if oil, gas or high grade "steam" coal is used. If there is considerable ash or if it has a low fusion point, air-cooled or partly water-cooled walls must be used. Conditions requiring forced draft are the same as for small boilers.

For pulverized fuel, direct firing is now the rule on boilers of this group. Bin and feeder installations are limited to extensions of plants already having this system. With natural draft horizontal or vertical burners, the air ports into the furnace should total two to eight square feet. Vertical burners (Fig. 6) are preferable if narrow furnaces, wide operating ranges, and a variety of coals are to be used. Horizontal burners (Fig. 3) are preferable if forced draft or combined firing with oil or gas is wanted or if a single burner can be used.

Only burners giving a "bushy" or "conical" flame (Fig. 3) should be used with horizontal firing. "Straight shot" horizontal burners (Fig. 2) which are satisfactory in some small furnaces are not applicable to medium size units, because flame lengths increase faster than furnace depth for increased boiler size and load. Natural draft vertical burners are "straight shot," but may be used because they give a long flame path in a short furnace. Single vertical burners do not do justice to

this arrangement so a minimum of two must be used.

If horizontal firing is used, and if only two to three square feet of furnace opening is required, one burner is sufficient. This costs less than two vertical burners with distribution system, furnace arch, and front wall ports. If larger furnace openings are needed, two or three horizontal burners are advisable because large natural draft pulverized fuel burners do not mix fuel and air effectively. This introduces fuel distribution as a requirement and also requires wide furnaces or double decked burners. In this case horizontal firing is no simpler than vertical firing. If furnace width is not a limitation, if burners and mills can be at the same floor level, if load ranges are not wide and if but one grade of coal is to be handled, horizontal burners are preferable when three or less are required, otherwise vertical firing with two to four burners should be used.

For oil, two to four steam atomizing burners or three to five mechanical atomizing burners should be used. Checkerwork floors (Fig. 1) can be used with steam atomizing burners but conditions do not favor them as much for medium size boilers as for small ones. Horizontal burners (Fig. 3) are preferable. Vertical firing is not suitable for fuel oil in medium size, low rating units, because the front wall may overheat. Conditions are somewhat different for waste oils. They are being successfully fired with horizontal burners, but vertical firing is more adaptable to the widely varying characteristics of such fuels. It provides a longer flame travel, with the flame close to an incandescent wall throughout the ignition period, which is desirable when high moisture or sediment content retards combustion. This system of firing waste fuels has unfortunately lagged because refiners are familiar with horizontal firing to the exclusion of other forms.

If combined firing of oil with pulverized fuel is wanted, the atomizers can be placed in horizontal coal burners. With vertical coal burners separate oil burners should be used (Fig. 12) unless oil is only auxiliary to coal. In this case flat flame steam atomizers may be inserted in the vertical burners. Other aspects of combined oil and coal or oil and gas firing which were discussed with reference to small boilers apply equally to medium-size, low rating boilers. For blast furnace gas one to three horizontal burners are used as with small boilers.

Refinements for High Rating Boilers

When new equipment for large quantities of steam is installed it is now customary to economize on boiler heating surface, operating it consistently at high rating and adding auxiliary equipment to produce the desired efficiency. The comparatively small boilers call for narrow short furnaces. The height of these furnaces is limited if they are to be efficiently proportioned. This leads to the use of high combustion rates. Narrow, shallow furnaces with high combustion rates must be extensively water cooled. If the furnace is completely water cooled it may be reduced in size and cost to a point where further reduction would result in such a high combustion rate that carbon loss would be excessive. This puts a premium on forced draft, preheated air and high velocity turbulent burners.

There are of course many high rating plants which lack some of the features discussed here, just as there are low rating plants which have some of these features. Variations in expected fuel costs, loads, sizes of units, plant growth, existing equipment, finances, and previous experience of purchaser and manufacturer all influence design. In spite of this, it seems reasonable that in time the distinction between high and low rating plants will be more marked, because the features required for high ratings are so interrelated that they are most economically applied together.

Forced draft burners, either with cold or with preheated air, permit much higher combustion rates than can be obtained with natural draft burners. With several inches of pressure in the burners, high velocities are obtained. Forced draft burners subdivide the combustion air, then recombine the several streams with impingement, producing eddy currents. These retard part of the fuel momentarily causing quick ignition. They continue and violently mix the fuel and combustion gases as the flame passes through the furnace.

With good burner design, the combustion rate attainable is proportional to the kinetic energy imparted to the fuel and air when pressure is converted to velocity at the burner outlet. For a given pressure and fuel, the same combustion rates can be obtained with any system of firing, or arrangement of burners, if the burners are so designed that pressure is not wasted within the burner and quick ignition is obtained. Frequently this is not understood and unjustified claims are sometimes made for special features of burner design which are supposed to give high combustion rates regardless of air pressure.

The furnace openings for air and fuel can be much smaller than with natural draft burners, and the capacities of individual burners can be much greater without loss of efficiency. The total furnace opening with the best designs is 2 to 3 sq. ft. per thousand boiler hp. of maximum output. The openings approach the lower figures where frequent operation at low loads is expected. They approach the higher figure if expected loads will be consistently close to the maximum design capacity.

One of the chief advantages of forced draft is the reduction of furnace leakage. When air is admitted under pressure the only draft necessary in the furnace is that which is unavoidably caused by the stack effect of the hot gases within the furnace. Forced draft not only reduces the difference in pressures inside and outside the furnace, but also permits a smaller furnace, with less area through which leakage can occur. When leakage is expressed as a fraction of the air required for combustion, it is inversely proportional to combustion

rate. This applies not only to different combustion rates in one furnace, but also to the difference in rates of burning the same quantity of fuel in two furnaces of different sizes. The importance of leakage is seldom realized. Air which leaks into a furnace is used for combustion, but it is poorly distributed, and enters at such low velocity, that it is useless for turbulence, and therefore cuts down the combustion rate attainable. It also reduces the air which passes through a preheater, for a given CO_2, unbalancing the weights of flue gas and air through the preheater, causing increased exit temperatures and loss of efficiency.

Leakage is a serious handicap to good operation unless settings are very carefully constructed. Furnace leakage is nearly a constant quantity at all combustion rates for given excess air and draft in a given furnace. A well built furnace which has 10 to 15 per cent leakage at 25000 B.t.u. combustion rate will have 25 to 40 per cent leakage at 10,000 B.t.u. per cu. ft. per hr. This is particularly important with pulverized coal burners. At the maximum load the primary air is 15 to 25 per cent of total air, and at 10,000 B.t.u. or 2/5 load, it is 30 to 50 per cent or more. This leaves little for secondary air, unless excess air is increased, so a burner which depends on mixing of primary with secondary air to obtain stable ignition cannot function effectively. If the furnace is poorly built, conditions would be impossible at 2/5 load. Even with oil and gas burners, where no primary air is needed, conditions are bad at low loads if only a small portion of the air mixes with the fuel immediately as it issues from the burner, with the rest seeping through the walls.

The selection of milling equipment for pulverized fuel depends on the same factors as the selection of burners, and has, in turn, considerable influence on burner arrangements. With direct firing systems, horizontal burners are most widely used, because they give the simplest layout. With storage systems the other firing arrangements are as readily applied, and they often give better operating conditions. Direct firing usually has the advantage of less complication, lower cost, and smaller space requirements. However, if the use of two or more coals having widely differing grinding characteristics is expected, it is desirable to segregate pulverization and combustion by using a storage system. In other cases, the expected load curve may permit a reduction in total milling capacity, or an increase in individual mill size if a storage system is used. This may offset the cost of conveyors, bins and feeders. In such cases a storage system is preferable, requiring less power and no outage of boiler capacity. Combustion is also better over a wide operating range, because turbulent burners are most effective when pulverization is uniform and air flow precisely controllable.

The factors bearing on selection of firing arrangements for different high rating installations have already been enumerated. Turbulent horizontal firing (Fig. 4) predominates for oil and gas and for pulverized fuel where one or two direct fired burners per furnace can take care of the load. Turbulent vertical firing (Fig. 7) for pulverized fuel is most generally found on larger units with storage systems. Opposed horizontal firing (Fig. 4) is a recent development for large units at plants where the floor plan permits this very desirable arrangement, especially where pulverized fuel equipment is added to units fired by blast furnace gas. Opposed vertical firing (Fig. 9) is found on large double ended boilers. Vertical firing with auxiliary nozzles (Fig. 8) is a recent development for low volatile coal, or for very large units, or for regulation of temperature in radiant superheaters. Tangential firing (Fig. 5) is used on installations having all the refinements of a high rating unit where high efficiency is wanted at high combustion rates.

Horizontal Firing of High Rating Boilers

Turbulent horizontal firing of pulverized fuel for loads up to 1500 boiler hp. is most simply obtained with one direct firing mill and one burner per furnace. Single burners have operated at loads up to 2500 boiler hp., but two burners give distinctly better flame distribution, completeness of combustion, operating range, and efficiency. Where continuity of operation is important, two mills should be used. This insures operation of the unit when feed from one mill is stopped by wet coal, foreign material, overloading or mechanical failure, and permits carrying load during mill outage for maintenance on coal gates, scales, feeder, mill, exhauster or piping. Provision of two mills would be justified on most units having over 1500 boiler hp. capacity, because of the increased availability of equipment costing many times as much as the difference in cost between one large and two small mills.

At some plants this idea has been carried to the extreme of providing two mills, either of which can carry nearly full boiler load. This seriously limits the operating range of a unit, because each mill feeder and each burner must be big enough for full mill load, unless feed pipes are interconnected. During normal operation with both mills running, each burner will be operating at 1/2 to 1/3 its best load, with poor flame conditions. These poor flame conditions would not be so serious if one of the burners was operating alone at that fraction of its normal load, with a low combustion rate in the furnace, but they do become serious when both of these oversize burners are in operation with a high combustion rate in the furnace. Combustion equipment on a unit should not total over 25 per cent excess capacity for a good compromise between flexibility and reserve capacity.

Some recent installations have two or three mills interconnected, with two valves at each junction in the piping. An extra standby mill is provided, or a mill in front of one furnace may be operated with a burner on an adjacent furnace. The desirability of this is questionable because it is nearly impossible to make these valves permanently tight and at the same time easily movable. If the valves are

not kept tight, if somebody opens one at the wrong time, or if the operator fails to use them properly in emergencies, the chance of an explosion is a hazard to property and life. The extra piping is very cumbersome unless primary air is reduced to a quantity which is insufficient for mill drying. These arrangements give reserve mill capacity at low cost, but they add nothing to those advantages of two mills and burners per furnace as previously enumerated.

On direct-fired installations having more than one mill per furnace it is desirable to cross the feed pipes in one of the ways shown on Fig. 13, to maintain good flame distribution when one or more of the mills, is idle. Three burners can be used in a variety of ways with two mills, for instance, one mill can supply two burners, while the third, fired by the second mill is used to help on peak loads, or when coal is wet. If the second mill is smaller than the first it may be used alone on light loads. Such arrangements are not very popular, because operating conditions differ for each combination, making it difficult for operators of average grade to obtain the best results.

The most suitable number of burners for various kinds of installations is shown in Table II. This table shows smaller burners for storage systems than for direct fired. The use of bins and feeders simplifies distribution so a large number of burners can be used advantageously to augment the flexibility of the storage system at little added expense.

With oil or gas firing, horizontal burners predominate, perhaps chiefly because they have become so highly standardized by manufacturers who specialize in burners. Water-cooled furnaces are becoming more common for such fuels, especially when pulverized fuel is a future possibility, but partially or completely refractory walled furnaces are still common. Refractory can be used, even at high combustion rates, because flames from these fuels are less luminous than coal flames. Moreover, there is no appreciable ash to contend with in fuel oil, or coke oven gas, none at all in natural gas, and the dust in blast furnace gas is not harmful to the walls because furnace temperatures with this fuel are so low.

For fuel oil or natural gas, any number of horizontal burners in one, two or three tiers can be easily installed and efficiently operated. This permits great leeway in furnace proportions. Layouts for such fuels differ from those for coal and blast furnace gas in that no provision for ash disposal need be made; distribution of fuel to any number of burners is easily and accurately accomplished through small pipes; the burners, air ducts, and fuel pipes interfere in no way with location of furnace steel work, or water wall connections; operation is confined to a single floor because there is no equipment to be operated other than the burners. Burners having capacities good for 200 to 500 boiler hp. each are generally used, but larger ones are becoming popular.

With forced draft there is nothing but flexibility of operation to prevent oil burners from being made with as high capacities as pulverized fuel burners. Mechanical oil atomizers must be cleaned regularly, so there should be at least one extra burner in each furnace, but on large units three or four large burners can advantageously be used instead of the dozen or more small ones now used. With steam atomization two burners of large size can be used for loads up to 2500 boiler hp. Where low first cost is vital, it is practical to use one steam atomizing burner for loads up to 1000 boiler hp. or even 1200 boiler hp., if oil is supplemented by combined firing with natural or coke oven gas. The gas feature may be nothing more than a strong pilot light, to be turned on while a clean oil atomizer is being substituted for a dirty one.

For blast furnace gas a few large multiple mixing high pressure burners are standard in refractory furnaces. With this fuel, it is now customary to provide auxiliary pulverized fuel equipment. Combination burners are not considered practical at present. Separate coal burners are sometimes installed in the same wall as the gas burners, but preferably in the opposite wall, because the two flames should not be mixed. With horizontal burners the gas flame tends to snuff out the coal flame, resulting in high carbon losses unless the coal is almost completely burned before coming in contact with the gas flame.

With very deep furnaces, horizontal burners in one end do not effectively fill the furnace. Opposed burners (Fig. 4) make the flames fill the furnace better, and produce secondary turbulence in the center which reduces carbon loss. This arrangement is usable with all types of fuel. Two firing aisles are needed, but they do not involve a large percentage of the floor space around large furnaces. With direct fired pulverized fuel half of the mills can be at each end or side, or all can be at one side. With opposed firing, perfect distribution of fuel between burners is not vital, so only two large mills need be used, each firing three to five burners at one end of the furnace. With oil or gas, this firing arrangement necessitates more water cooling in the furnace than is needed when all burners are in one wall. This is hardly a disadvantage, because water walls on the large units justifying opposed firing are comparatively inexpensive heat absorbing surface.

Vertical Firing of High Rating Boilers

Vertical firing with its long flame travel, simple and accessible burners, controllable fuel distribution, and easily adjusted air admission was the first arrangement widely used for firing boilers with pulverized fuel. When direct firing became general, it was found difficult to properly distribute the fuel. The accurate control of primary air, which was imperative with vertical burners, was impossible with early direct-fired mills. Moreover, with increasing combustion rates, and the use of preheated air, front wall maintenance became excessive. Difficulties with direct firing have now been overcome by improved designs of distribu-

tors, properly proportioned fuel piping, more efficient mill design, permitting a reduction in carrier air, and by the use of controllable tertiary air admitted to the burner under pressure to supplement the primary air when necessary. Front wall maintenance was eliminated when it was found that completely water cooled front walls could be used, without jeopardizing ignition, if burners were properly proportioned with turbulent nozzles.

With the disadvantages largely overcome by recent developments, this type of firing can now be efficiently used with some types of direct fired mills, or with storage systems, where boiler room proportions are suited to this arrangement, and where wide operating ranges with easy adjustments for a wide variety of fuels are wanted. Direct firing mills are usually put in the basement of plants having large steam units. This necessitates two operating floors with any burner arrangement, so vertical firing does not suffer by comparison with the others on this point.

The storage system is favorable to vertical firing. Aisles between furnaces can be narrow and the burner arch can be used as part of the operating floor, with feeders accessible from the same floor. The use of feeders permits any number of vertical burners, with no difficulties in fuel distribution, and it permits independent control of primary air to suit burner conditions.

Vertical burners may be proportioned for either narrow, or bushy flames, but in no case will the flame be as bushy as with a turbulent horizontal burner, so a large number of vertical burners is needed to properly distribute the flame (see Table II. For most cases the arrangement in Fig. 7 is used, but the arrangement shown in Fig. 8 is desirable in some cases. With this system a small amount of primary air picks up the coal at the feeder. About a fifth of this stream is tapped off to a small auxiliary nozzle giving a bushy flame. Just enough secondary air to give good ignition is admitted around this nozzle. The main stream receives enough additional primary air to give a strong jet at the burner, which is further augmented, and made turbulent, by the admission of tertiary air under pressure. Little more than half the controlled air remains to be admitted through the front wall. The burners are directed slightly toward the front wall, so secondary air impinges on the vertical stream while at high velocity, just after leaving the front wall ports. This arrangement involves complications which are only justified when low volatile coal is to be fired through a number of very large burners on a storage system.

For direct fired vertical burners a system somewhat similar to Fig. 8, but simpler has been used to equalize temperatures in radiant superheaters. With this system a small line tapped into each main feed pipe carries some of the primary air and fuel to auxiliary horizontal burners at the bottom of the front wall. The number of auxiliary nozzles in use can be varied by means of shut-off gates at the top of the auxiliary feed lines.

With turbulent vertical firing in furnaces having complete water cooling, including the front wall, there is a tendency to use an increasing por-

TABLE II

SUITABLE NUMBER OF BURNERS FOR VARIOUS INSTALLATIONS

Maximum Developed Boiler hp.	Direct Fired Pulverized Fuel Burners with Natural Draft: 1 Mill per Furnace, Fig. 2	1 Mill per Furnace, Fig. 3	1 Mill per Furnace, Fig. 6	2 Mills per Furnace, Fig. 3	2 Mills per Furnace, Fig. 6	2 Mills per Furnace, Fig. 7	3 Mills, Fig. 3	Oil and Natural Gas with Natural Draft: Steam Atomizing, Fig. 1	Steam Atomizing, Fig. 3	Mech. Atom., Fig. 3	Blast Furnace Gas, Fig. 3
Up to 600	1	1	(2*)	*	*	*	*	1 or 2	1 or 2	(2 or 3)	(1)
Up to 1000	2*	1 or 2	2	*	*	*	*	2 or 3	1–3	2 or 3	1
Up to 1500	*	(2)	3	(2)	*	*	*	*	2–3	2–4	1 or 2
Up to 2000	*	2*	3 or 4	2	4	(4*)	(3)	*	2–4	3–5	(1–3)
Up to 2500	*	*	4*	*	4 or 6	4*	3	*	2–6	3–6	1–3

Maximum Developed Boiler hp.	Direct Fired Pulverized Fuel Burners with Forced Draft: 1 Mill per Furnace, Fig. 3	1 Mill per Furnace, Fig. 7	2 Mills per Furnace, Fig. 3	2 Mills per Furnace, Fig. 4	2 Mills per Furnace, Fig. 5	2 Mills per Furnace, Fig. 7	3 Mills per Furnace, Fig. 3	3 Mills per Furnace, Fig. 7	4 Mills per Furnace, Fig. 3	4 Mills per Furnace, Fig. 4	4 Mills per Furnace, Fig. 5	4 Mills per Furnace, Fig. 7
Up to 1500	1	3*	(1 or 2)	*	*	*	*	*	*	*	*	*
Up to 2000	1 or 2	3 or 4	1 or 2	*	(4*)	(4*)	*	*	*	*	*	*
Up to 2500	2*	4	(2)	*	4	4	*	*	*	*	*	*
Up to 4000	*	*	2	*	4 or 8	4 or 6	(3)	6	2 or 4	*	(8)	(8)
Up to 5000	*	*	2 or 4	*	(8)	6 or 8	3	6 or 9	(4)	*	(8)	(8)
Up to 8000	*	*	4	4 8	(8)	8	3 or 6	9	4	4 or 8	8	8
Up to 12000	*	*	4 or 6	4 10	8	*	6	9 or 12	4 or 8	(8 or 12)	(12)	(12)
Up to 15000	*	*	*	*	*	*	6*	12	8	8 or 12	12	12

Maximum Developed Boiler hp.	Pulverized Fuel Burners with Storage Systems: Natural Draft, Fig. 3	Natural Draft, Fig. 6	Forced Draft, Fig. 3	Forced Draft, Fig. 4	Forced Draft, Fig. 5	Forced Draft, Fig. 7	Forced Draft, Fig. 8	Forced Draft, Fig. 9	Oil & Nat. Gas Forced Draft: Steam Atom.	Mech. Atom.	Blast Furnace Gas, Continued: Fig. 3	Fig. 5
Up to 1200	2*	3*	1*	*	*	2*	*	*	1 or 2	2 or 3	1	*
Up to 2500	3*	4–6	(2)	*	(4)	3–5	*	*	2–4	3–5	1–3	(4)
Up to 3500	*	5–8	2	*	4	5–7	*	*	3–6	4–8	2–3	4
Up to 6000	*	*	3	*	(8)	6–9	*	*	4–8	5–10	2–4	(8)
Up to 9000	*	*	4	4–8	8	7–12	*	*	5–10	6–12	3–6	8
Up to 12000	*	*	5	6–10	(12)	8–14	7–9	8–14	6–12	7–14	*	(12)
Up to 15000	*	*	6	6–12	(12)	9–16	8–10	10–16	7–14	8–16	*	12
Up to 18000	*	*	7 or 8	8–14	12	10–18	9–12	12–18	8–16	9–18	*	*
Up to 25000	*	*	*	10–16	12 or 16	11–20	12–16	16–22	*	*	*	*
Up to 40000	*	*	*	*	16	*	16–20	18–24	*	*	*	*

* Asterisks alone indicate arrangements which have not been used, or are not being used on modern installations.
Asterisks after numbers indicate arrangements used, but not favored (see text).
Parentheses indicate number of burners in cases where the load is not considered the limit for that number of burners.

tion of the total air through the burners. Burner designs now permit this without jeopardizing ignition because means for insuring turbulence have become better understood. In the future perhaps all the combustion air will be introduced through the burners, eliminating the need of front wall ducts and air ports, and resulting in layouts as simple as those now made with horizontal firing, and with the turbulence now so effectively obtained with horizontal burners, but with the long flame travel, simple burner design, and effective filling of the furnace, which are the chief advantages of vertical firing.

Opposed vertical firing is particularly adapted to double end boilers which have narrow deep furnaces. In order to obtain sufficient volume in these furnaces, it is necessary to have an arch under each mud drum. Bins and feeders can be set above these arches, and vertical burners can be set in them, so walls of adjacent furnaces may be closer together than with any other firing arrangement.

Tangential Firing of High Rating Boilers

Tangential firing (Fig. 5) was developed to fill a need for high sustained combustion rates with low excess air. It is particularly applicable for pulverized fuel firing in large furnaces where the ratio of heat liberated to wall area is high. The coal ash will slag the boiler tubes unless the furnace gases are cooled below the fusion point of the ash. This is accomplished most effectively with the tangential system, because it makes the flames brush all four furnace walls.

As the size of units increases, it becomes more difficult to create sufficient turbulence at the burners to last effectively till combustion is complete. With tangential firing, this is unnecessary. Only enough turbulence to insure quick ignition is imparted at the burners. Most of the energy is retained in the high velocity streams. Prolonged turbulence is created when these streams mix and whirl. Thus turbulence occurs where it will do the most good, and at the same time long flame travel is obtained.

Tangential firing is inherently a high rating arrangement. High rating units are becoming more generally used, permitting greater standardization. This should enlarge the field for tangential firing unless radical new developments occur on one of the other arrangements. It is applicable with any fuel where completely water-cooled furnaces and forced draft can be justified, unless the boiler or building limitations necessitate a narrow deep furnace, or render impossible the installation of feed pipes and ducts to each furnace corner.

With this firing arrangement, there may be one set of burners in each furnace wall, normal to the wall, or two sets of burners in each side wall, near the corners, or the burners may be set exactly in the corners. The last is preferable. The first gives good flame conditions, but probably no better than the others, and has now been abandoned because of the difficulty in avoiding interferences between air ducts, feed piping, steel work, water wall connections and boiler. The burners are located in walls near the corners if building columns are unavoidably at the corners, otherwise the burners are exactly in the corners, because this requires less bending of wall tubes and permits a better nozzle shape. There are one to four nozzles in each corner, as indicated in Table II.

Tangential firing has been found particularly applicable to blast furnace gas, especially when pulverized fuel has been adopted as standby to gas. The precautions needed with horizontal firing to keep coal flames and gas flames separate are not necessary with tangential firing, because of the prolonged turbulence obtained. It used to be assumed that blast furnace gas needed incandescent furnace walls as an aid to combustion. It is now known that water cooled walls do not interfere with combustion if burners are properly designed. Much higher combustion rates can be used than with present horizontal designs and can be obtained efficiently and with lower gas and air pressures, due to the efficient conversion of these pressures to velocity, without dissipation in the burner.

When an auxiliary fuel is needed for emergencies, with pulverized fuel or blast furnace gas, tangential burners are supplied with coke oven gas pilot lights, or with steam atomizing nozzles for oil or tar.

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X-ray Examination of Welded Pressure Vessel Seams

(*Continued from page 20*)

The novel feature embodied in this new design is the operation of two X-ray tubes at the same time, enabling thirty-four inches of welded seam to be radiographed simultaneously. This is a highly important factor. The two X-ray tubes shown in Fig. 10, have a raising and lowering device capable of a 15 in. shift and can be raised or lowered independent of each other by controls on the control panel side of the container.

An up-to-date dark room has been installed in close proximity to where the radiography of the pressure vessels takes place. It is built with a maze, thereby eliminating all doors. It is equipped with a film drier which facilitates the handling of films in large quantities and enables a complete inspection from dry films in one-half hour.

With this equipment it is possible to radiograph a thickness of boiler plate of five inches. It is capable of radiographing two-inch boiler plate in fifteen seconds. In actual operation, a boiler drum seam, 17 ft. long with 1¼ in. wall thickness, was radiographed in fifteen minutes, which includes the time necessary for the changing of the cassettes. The use of two tubes simultaneously in the X-raying of longitudinal seams permits of both rapid radiography and ample exposure time.

An X-ray installation, such as this, enables the boiler manufacturer to verify the results of his welding process and thus places him in a position to assure the satisfactory performance of the welded drums manufactured in his plant.

Chemical Correction of Corrosion and Pitting

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The author states that if caustic corrosion is considered as a distinct phenomena, then normal corrosion is simply the action of an acid or acid gas to form a ferrous or ferric salt. The obvious methods of correcting this action would be either to completely eliminate acids and acid gases or to provide some other base or metal with which these gases would combine. This article is limited to a discussion of corrosion from gases, particularly oxygen and carbon dioxide . . . After considering various aspects of the problem, the author discusses methods of solution and then presents several case studies based on actual installations.

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UNTIL 10 or 15 years ago, the only boiler water conditioning generally practiced involved the use of boiler compounds. In very few cases was scientific reasoning applied to such water treatment with the consequence that inefficient results were obtained and chemical treatment in general fell into disrepute. The trend away from internal chemical treatment was given further impetus by the equipment manufacturers who adopted the slogan, "Do not make a treating plant of your boiler."

Notable research conducted in the past six or eight years has brought to light data relative to the conversion and formation of salts under high temperatures and pressures. These facts have given convincing evidence that the boiler is and must be to a certain extent "a treating plant," since the criterion of efficiency in any case is determined by the condition of the water in the boiler. Even though the water is pretreated to remove scale forming matter, it is frequently advisable to add chemicals to the boiler to completely prevent scale. The addition of sodium sulphate or phosphate to the boiler to prevent embrittlement or caustic corrosion is such standard practice as to require no comment. The chemical treatment of the water for the prevention of normal corrosion or pitting, however, does not seem to have received its full quota of consideration.

Like any other problem, the elimination of corrosion and pitting cannot be accomplished without a definite understanding of the phenomena. When we appreciate that pitting is merely localized corrosion and when we further appreciate that corrosion is simply the act of forming a salt by combination of a negative radical with a base, we will have taken much of the mystery out of the subject. If we consider caustic corrosion as a distinct phenomena we can state that normal corrosion is simply the action of an acid or acid gas to form a ferrous or ferric salt. The obvious direct means of preventing this action would be either the complete elimination of acids and acid gases or else to provide some other base or metal with which these gases would more readily combine. The question as to which of these methods is preferable is the real problem and its answer is entirely dependent upon existing conditions. We are limiting the scope of this paper to corrosion from gases and more particularly to corrosion from oxygen and carbon dioxide.

Undoubtedly, the most familiar piece of equipment used in corrosion prevention is the deaerating heater. This equipment depends for its functioning on the fact that increased temperature tends to break down some of the gas liberating salts and also increases the volatility of the gases. A properly designed heater also provides for the passage of steam through the water contained in the heater in such fashion as to sweep the liberated gases out through the vent. It follows that the higher the temperature obtained and the longer the water is retained in the heater the more complete will be the gas removal. A correctly designed deaerating heater of sufficient capacity to retain the water at a temperature of at least 215 deg. for a period of at least five minutes should completely eliminate carbon dioxide and should leave a residual oxygen content of about 0.3 p.p.m. or 0.25 cc. per liter.

If the water is untreated or if it is zeolite softened there is generally present some calcium, magnesium or sodium bicarbonate. These bicarbonates break down under the action of heat to form normal carbonates, free carbon dioxide and water. This decomposition is seldom or never completed in the heater with the result that even though the gas liberation in the heater may be entirely satisfactory, there will likely be further liberation of free carbon dioxide at the higher temperatures obtained in the boiler.

It is evident then, that although a dearating

heater may be highly efficient in the removal of dissolved gases, it does not necessarily assure ultimate protection from corrosion. Fortunately, if sufficient alkalinity is maintained in the boiler, the normal corrosive tendency of these gases is virtually eliminated. Thus, according to Hall*, if the pH value of the water in the boiler is maintained at a minimum of 9.6 corrosion will not take place. It would appear that there was no particular advantage in the use of a deaerating heater to attempt to keep carbon dioxide out of the boilers, since it is virtually impossible to remove all of the potential carbon dioxide and so protection will have to be obtained by adjustment of the pH value of the water in the boiler. Feedwater line corrosion however presents a different problem since if dissolved carbon dioxide were not removed in the heater it would attack the feedwater lines. Chemical protection by correction of the pH value at this point would be out of the question since the amount of chemical necessary would concentrate in the boiler so rapidly as to be a very possible source of trouble. Summing up then, we might say that free carbon dioxide should be removed in the heater to prevent feed line corrosion but pH adjustment should be maintained in the boiler to prevent corrosion at that point.

When we are confronted with the presence of dissolved oxygen we must take other factors into consideration. Theoretically, oxygen will not cause corrosion in a sufficiently alkaline water. Actually, however, oxygen may be liberated from solution by virtue of the increased temperature in the boiler and form bubbles. These bubbles may adhere to the metal thus excluding the alkaline water from contact with the metal at that particular point and allowing localized corrosion or pitting to progress. Also, if scale is present oxygen may accumulate under a scale blister and again by virtue of preventing alkaline water from contacting with the metal, pitting may progress. The same thing holds true with the use of certain so called protective coatings unless these coatings are adherent enough to prevent blistering. It would appear then that the only satisfactory insurance against pitting from oxygen is the complete elimination of oxygen.

It cannot be positively stated that the presence of dissolved oxygen will cause pitting. Vagaries of circulation and methods of feeding as well as peculiarities of construction all have a vital bearing on the situation. For example, if the feedwater is sprayed into the steam space oxygen will be largely liberated there and pass out of the boiler with the steam. This is not objectionable unless the condensate lines are lengthy such as in a heating system. In such cases corrosion is liable to occur in the condensate lines. Again, if the feedwater is zeolite softened or for some other reason has bicarbonates present there will be appreciable amounts of free carbon dioxide liberated. Since the metal in the steam space is not protected by the alkaline water, corrosion may occur in such cases. Of course, if the water were properly treated with lime and soda ash there would be no bicarbonates and it would be entirely safe to feed the water above the water line provided excessive hammering did not take place. Such hammering would be likely only when plunger pumps were used for boiler feeding.

In water tube boilers the pits usually occur at the bends of the tubes particularly when the bends are at a hot point and are near the feedwater inlet. Sometimes it is possible to stop pitting simply by changing the circulation or feedwater inlet so that the water will pass through the straight and comparatively cooler tubes before it reaches the hotter bent tubes. This depends entirely on the construction of the particular boiler in question. Such methods may prove corrective to a large degree but are not for general use except when recommended by a chemical engineer of thorough experience in this particular field.

It would seem from the foregoing discussion that utter oxygen elimination is frequently, if not always, desirable. The vital question is how most economically to effect utter elimination. A deaerating heater will not give utter elimination unless the retention time and temperatures are greater than is usually the case. The extra cost of oversized equipment is frequently a factor. In a great many industries, the vagaries of load requirement do not allow a sufficiently high and constant temperature to be maintained. Frequently the load requirements have been increased and the heater is no longer large enough to meet these requirements. In such cases is it necessary to purchase a new heater or is it more economical to eliminate oxygen chemically?

There are a number of chemicals known as reducing agents which have the ability to absorb oxygen. A reducing agent to be used in a boiler must have certain qualifications. In general it can be said that it must combine with oxygen in alkaline solutions more readily than does the metallic iron. The product resulting from the reaction must not in any way be injurious to the boiler. There must be no secondary products to the reaction which are injurious. It must also be reasonably cheap.

Ferrous sulphate has been used internally as a reducing agent for the elimination of dissolved oxygen in boilers. It meets some of these conditions under proper circumstances but has some objectionable features. Ferrous sulphate reacts with the natural or artificial alkalinity to produce hydrous ferrous oxide which in turn takes up one molecule of oxygen for every two molecules of iron to form hydrous ferric oxide. If sufficient sodium hydroxide is present in the boiler water, the second product of the reaction is sodium sulphate which may prove valuable in the prevention of embrittlement. If all the sodium hydroxide present is the result of hydrolysis of sodium carbonate then further hydrolysis will take place to maintain equilibrium. Since the process of hydrolysis lib-

* R. E. Hall—Combustion—May, 1931.

erates free carbon dioxide it will be necessary to take that fact into consideration. If there is insufficient sodium alkalinity to react with the ferrous sulphate, the reaction will occur with calcium bicarbonate to produce calcium sulphate which may cause scale. The fact is that if sufficient alkalinity is maintained in the boiler to prevent carbon dioxide corrosion there will be sufficient sodium to react with the ferrous sulphate and no scale will be formed.

The hydrous ferric oxide is a highly amorphous precipitate and is an excellent coagulant where suspended matter is present. It may cause foaming however in the presence of high concentrations of solubles and when there is insufficient suspended matter to weight the precipitate down. The ferric oxide colors the boiler metal and water with the appearance of rust but this should cause no trouble or alarm unless the water carries over and contaminates some process steam.

Another chemical has been used by the author which does not seem to have so many complexities. This is sodium sulphite (Na_2SO_3). This salt takes up one molecule of oxygen to form sodium sulphate (Na_2SO_4). It does not reduce the alkalinity and there is no other product to the combination. Both salts are soluble and do not produce any suspended matter and of course the sodium sulphate is valuable in maintaining the correct sulphate carbonate ratio for the prevention of embrittlement.

Each 1000 gal. of water require 0.133 lb. of commercial sodium sulphite for every part per million of dissolved oxygen in the actual boiler feedwater. (1 p.p.m. of oxygen equals 0.698 cc. per liter.) This material can be purchased for about ten cents per lb. in small quantities which gives a cost of 1.33 cents for each 1000 p.p.m. of oxygen removal.

Since it is not feasible to attempt to run the dissolved oxygen on boiler water or condensate samples to determine the efficiency of treatment, it is preferable to insure complete oxygen removal by maintaining an excess of reducing agent in the water. The amount to be maintained is somewhat dependent upon the amount of oxygen in the feedwater but in general two or three grains of residual reducing agent should be ample.

In plants where sulphates are determined by turbidimeter after precipitation with barium chloride, the same method can be used for determination of sulphite. Simply acidify the sample with hydrochloric acid and precipitate the sulphates with an excess of barium chloride. Determine the sulphates by turbidimeter standards and then filter the sample and add bromine water. This will convert the sulphites to sulphates and cause a further precipitation of barium sulphate which can again be checked by the turbidimeter standards to give sulphite content.

In cases where control tests are made by colorimetric titrations for alkalinity and chlorides, corrections will have to be made when using sodium sulphite. Since silver sulphite is insoluble it is apparent that both the chloride and sulphite will be included when silver nitrate is titrated against potassium chromate. One half of the sulphite is also included in the methyl orange test for total alkalinity. The following method is simple and accurate enough for ordinary boiler water control.

Draw two samples of boiler water and to one add one cc. of concentrated hydrogen peroxide. Allow both to cool to room temperature and then titrate with silver nitrate solution against potassium chromate. The sample to which the hydrogen peroxide was added will give total chlorides while the difference between the two samples will give total sulphites. (There is a slight difference in combining weights but not enough to warrant correction in ordinary boiler water control.) One half of the total sulphites should be deducted from the methyl orange alkalinity but not from the phenolphtalien alkalinity.

The following cases should give some idea of the application of the foregoing discussion and principles. In each of these cases, the raw water contained about 3.5 grains of calcium and magnesium bicarbonates and about three grains of magnesium sulphate. The water was zeolite softened in each case which of course converted all of the calcium and magnesium salts to the corresponding sodium salts.

Case number one was a cross drum water tube boiler of 250 hp. installed in a laundry and operated at about rating with some 70 per cent makeup. One heater was used for both laundry water and boiler feed which made it inadvisable to raise the temperature higher than 180 deg. The raw water contained about 8.5 p.p.m. of dissolved oxygen due to aerating at the city water plant. The oxygen content of the boiler feedwater averaged about 1.5 p.p.m. Water was fed into the upper rear drum and steam was taken from the same drum. Extremely high chloride content gave very high solubles in the boiler water and a continuous blowdown was installed to correct that trouble. Ferrous sulphate was introduced into the boiler but caused violent foaming. Treatment was changed to sodium sulphite and no foaming was experienced. Prior to treatment pitting in the bends of tubes had caused the loss of an average of three tubes a month. In the six months since treatment was started no tube losses have occurred and no pitting or corrosion has been noted.

Case number two was also a laundry using the same make of boiler and the same water conditions. Again pitting had occurred in the bends of the tubes. This boiler, however, was fed into the lower drum and was badly scaled. The scale was removed and further scale formation prevented by using all zeolite softened water whereas they had used part hard water with the idea of preventing the pitting. Ferrous sulphate was again tried and in this case no foaming was experienced. This was probably due to the old scale dissolving and weighing down the precipitate. After three months the scale was completely removed and the boiler

began to show signs of foaming. At four months this was so serious that treatment was changed to sodium sulphite and no further trouble was experienced. No flue losses or pitting has been experienced in six months.

Case number three was also a laundry using the same boilers and water. In this case the water was fed into the steam drum and above the water level. Corrosion was experienced above the water line and serious pitting occurred at the bends of the flues causing as many as four tube failures in a month. Continuous blow-down was installed to reduce the high chloride concentration and ferrous sulphate was introduced to stop the pitting. Pitting stopped at once but corrosion above the water line became very much more pronounced. Believing that the additional corrosion was due to the additional carbon dioxide liberated by the use of ferrous sulphate the treatment was changed to sodium sulphite. This did not entirely stop the corrosion above the water line and since the water level was very low in the back drum on account of restriction in the tube area between the two upper drums it was decided to feed into the lower drum. This change at once stopped all corrosion in the upper drum and in the past six months no pitting has occurred and no corrosion has been noted at any point since the final change was made. In each of these cases the total chemical cost is less than fifteen cents per day.

In view of these facts and cases and in view of a great number of similar cases not here reported, the writer offers the following conclusions:

First: that it is advisable to mechanically remove gases as far as is consistent with economical operation.

Second: that it is frequently highly desirable to supplement such removal by chemical correction.

Third: that any attempt to correct corrosion or pitting difficulties must be made with full knowledge and consideration of all the various phenomena involved.

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Selsyn Devices and Their Applications

(*Continued from page 25*)

syn driven by gears from the cam shaft of the control drive through a rotation of 180 deg. for full travel. This Selsyn is electrically connected to a receiver in the other control drive. The rotor of the receiving Selsyn will assume a position relative to the transmitting Selsyn determined by the position of the transmitter, consequently the other control drive. The stator of this Selsyn is geared to the drive in which it is installed, also making 180 deg. rotation for full travel.

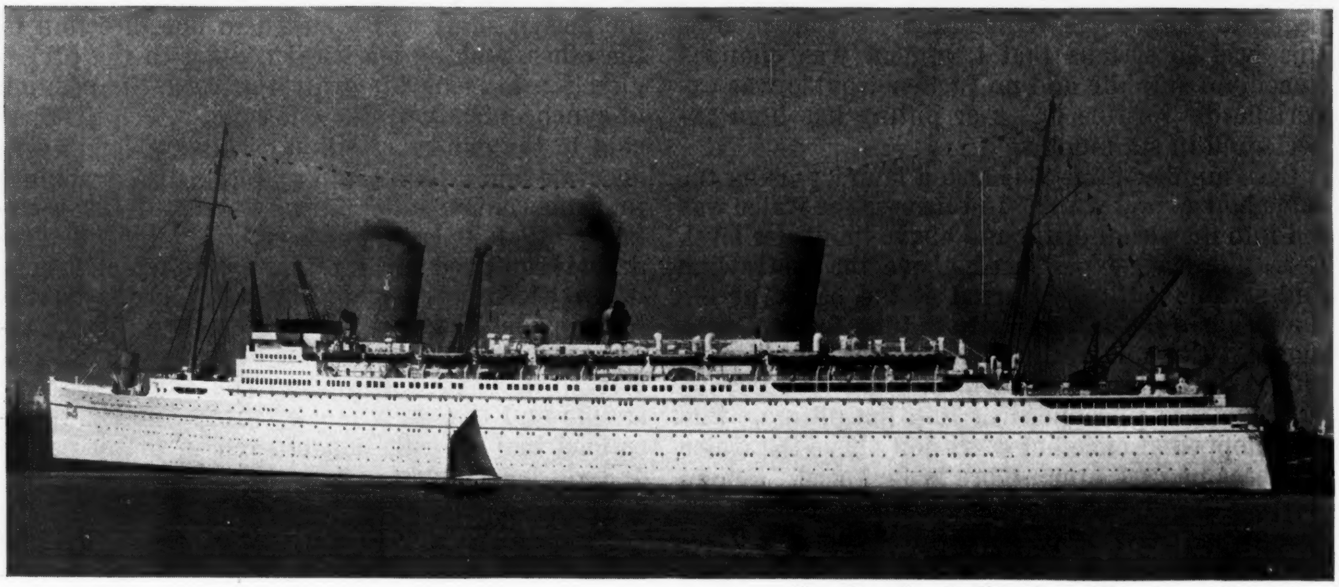
If one of the control drives then is in a different position from the other, the relation between the rotor and stator of the receiving Selsyn will be changed and a double ended mercoid fastened to the Selsyn shaft will be tilted in one direction or the other, making electrical contact in the proper direction to bring the control drive to the position of synchronism with the other and return the mercoid to the neutral position. This system is very accurate and reliable, and maintains the machines in synchronism automatically without the assistance of an operator. In addition, each control drive is equipped with another Selsyn which is connected electrically to a position indicator on the boiler panel board, so as to keep the operator always informed of the position of each control drive, consequently each damper. The system is very simple and is merely one of many similar applications that may be encountered in many power or industrial plants.

All of the applications and equipment previously mentioned employ Selsyns of standard design for indicating a single factor. At times it may be desirable to have a single record or indication which is the algebraic sum of two factors. The differential Selsyn permits this to be accomplished readily with Selsyn devices.

The differential Selsyn is practically the same in construction as the standard Selsyn previously described except that the rotor has a distributed three-circuit Y-connected winding, and three collector rings instead of two are necessary to bring out the rotor winding leads. The differential Selsyn in operation is interposed between two Selsyns used as transmitters and acts as a third point of control. If the two transmitting Selsyns in this system are rotated, the differential Selsyn will indicate either the sum or the difference of the angle through which they have been turned. If one of the Selsyns is locked in place and one of the other Selsyns is turned, then the third one will indicate the angle through which the first has rotated as in any two-Selsyn system.

A differential Selsyn is not connected to the supply source but instead the rotor is connected to the three stator leads of one transmitter while the stator is connected to the three stator leads of a second transmitter in the usual manner. This means that excitation for the differential Selsyn must be furnished through one of the transmitting Selsyns which must necessarily be wound special to have ample capacity and prevent over heating. The second transmitting Selsyn, however, is of standard design as used with the equipment previously described. The transmitter which is to furnish the excitation current for the differential Selsyn is merely a special design of standard apparatus and is commonly designated Selsyn exciter. It may function in the system either as a transmitter or receiver and some times in more complex systems, it merely floats on the system as an excitation supply to the differential unit. Due to these characteristics, the differential Selsyn can be readily installed in a suitable case to give a continuous indication or record of the sum or difference of two factors such as the flow of fluids as

(*Continued on page 46*)



New Canadian Pacific Liner, "Empress of Britain"

Marine Steam Generation

By DAVID BROWNLIE, London

The Canadian Pacific Liner Empress of Britain with a New British Design of Water Tube Boiler Approaches the Latest Power Station Practice.

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Following some general comments on marine boiler practice, Mr. Brownlie gives a detailed description of the power plant on the new Canadian Pacific liner, the Empress of Britain. The steam plant on this ship is comparable with the most modern stationary plants and in this fact, it signifies a new era in marine boiler practice which, for the most part, has lagged far behind land practice.

UNTIL the past few years the steam boiler installation of the large liner, often with a power plant of from 35,000 to 50,000 hp., has almost invariably been designed and operated on grossly unscientific principles, representing a stage of evolution about a quarter of a century behind that of a modern land power plant of similar size.

Essentially a liner is a large floating power station, and we are rapidly arriving at individual marine plants of 200,000 hp. far larger than most electricity stations, as represented by the gigantic new Cunarder, over 1,000 ft. long, designed for 30 knots normal speed and 32 knots maximum, and now under construction on the Clyde.

Until quite recently, however, the average steamship company, even when owning a fleet of vessels, not only refused to display the slightest interest in fuel economy, but generally maintained an active hostility to anything up-to-date in this connection. While, of course, there have been some exceptions, I write from considerable practical experience in trying to interest steamship companies in the matter and this has been the attitude most frequently encountered. The general position was well summed up by the chief engineer of one well-known company who, when driven into a corner by argument, assured me that he, as well as his directors, did not care particularly whether they wasted coal or not as if the profits began to diminish they would simply increase the passenger rates to make good the difference.

A typical example of this attitude is that the mercantile marine of the world has always, as a whole, refused to use water tube boilers, high steam pressures and superheat temperatures, mechanical stoking, pulverized fuel, combustion recorders, air heating, feedwater economizers, pyrometers, boiler feed meters, and other accessories representing almost elementary practice on land. During the past few years, however, matters have altered, simply because of the dwindling of profits on both passengers and freight, and a relatively limited number of merchant ships are now equipped with a number of the above items. The majority, however, still operate under conditions of Scotch cylindrical boilers, pressures of less than 300 lb. per sq. in., no air heaters or feedwater economizers, and complete and blissful ignorance as to

the performance of the steam generation plant. For example, one of the best known British feed-water meters was invented over 50 years ago, especially for marine work, and although many thousands of these meters have been supplied for land plants it is only within quite recent times that a few marine boiler plants have been equipped.

The Empress of Britain signifies definitely that this lamentable state of affairs is coming to an end. It is equipped with a water tube boiler plant much superior in design and operation to the average power station, and approaching that of the latest superpower station practice. One of the nine water tube boilers installed is of a new design, the invention of Mr. John Johnson, Chief Engineer of Canadian Pacific Steamships Ltd., whom I have to thank for the photographs used in this article.

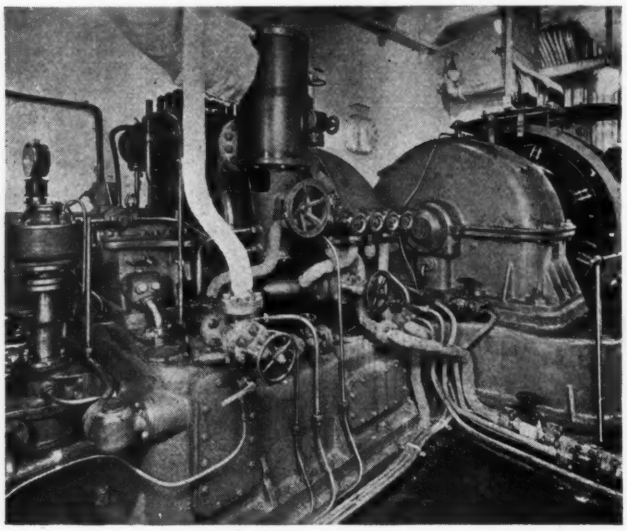
The vessel has been constructed throughout by John Brown and Co. Ltd., of Clydebank, which company built the Lusitania and now has in hand the new 30 to 32 knot Cunarder previously referred to. It is 42,348 tons gross, the largest vessel launched in Great Britain since the War. The length is 760 ft. 6 in., the moulded breadth 97 ft. 6 in., and the loaded draft 32 ft., with drive by means of quadruple screws, each operated by an independent single reduction geared turbine of Parsons type. These turbines are in two main engine rooms, and the maximum shaft horsepower is 66,500, capable of driving the vessel at 25.5 knots, although the normal speed is 24.0 knots, taking 63,000 shaft hp.

Two of the turbines are inboard, each of 21,000 shaft hp. while the other two are outboard, each 10,500 shaft hp. An overload of 5 per cent can, however, easily be carried for long periods. The reason for this arrangement is that the Empress of Britain is to run during the summer, as at present, on the Southampton-Quebec Route, having commenced her first voyage on May 27, 1931, with the normal speed of 24 knots, representing about 63,000 shaft hp. In this way the voyage from Europe to America is cut down to 3½ days in the open Atlantic, with 1½ days in the calm waters of the St. Lawrence. Fast trains from Quebec permit quick travel to New York, Chicago, Detroit, and all the chief towns in the United States and Canada. The above performance represents average Atlantic conditions, but in the event of partial stoppages due to fog or other troubles, the vessel can operate at 25½ knots and make up the lost time, maintaining a regular time table service between Southampton and Quebec. In winter, however, luxury cruising is to come into operation, when normally the two inboard turbines only will be used, that is 42,000 shaft hp., giving a speed of 22½ knots.

The turbine sets comprise one high pressure, one intermediate, and one low pressure unit working

One Johnson boiler and two Yarrow boilers for the Empress of Britain in the shops at Clydebank.

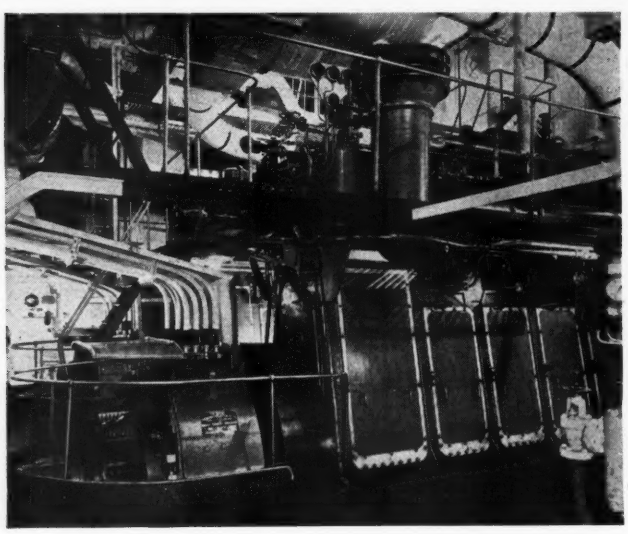
in series, and each turbine drives a separate pinion, as indicated, the operating conditions being a maximum of 425 lb. per sq. in. at the stop valve



Auxiliary turbo generators.

and 725 deg. fahr. superheated steam temperature, although both the normal and the overload outputs are obtained with 275 lb. and 700 deg. fahr. It is interesting to note, because of the relatively high steam pressure, that the turbine casings are of cast steel, with the exception of the low pressure portions, these being cast iron.

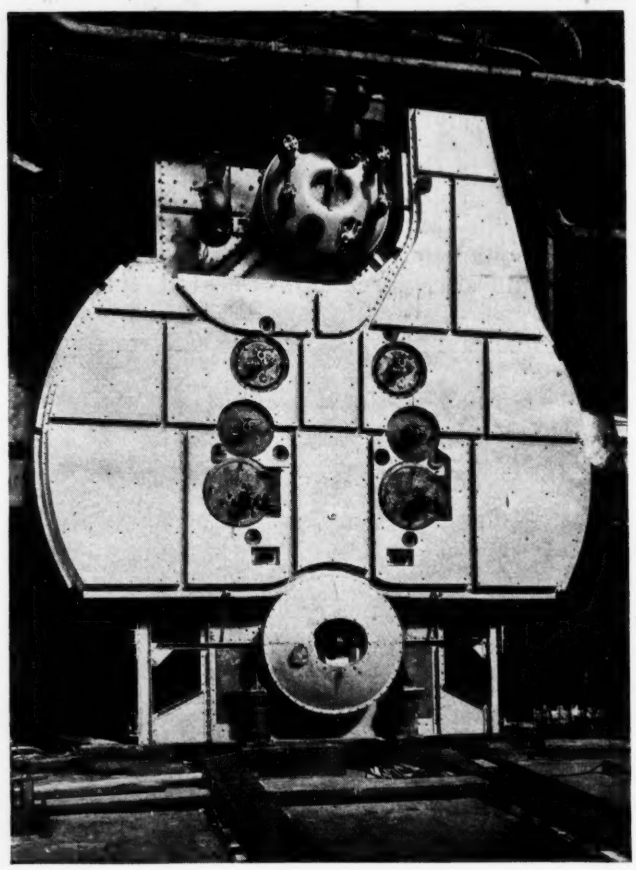
Also the main condensers are of the Weir two-flow regenerative type, situated underneath the low pressure turbines, while each of the inboard condensers has a cooling surface of 20,700 sq. ft., with ¾ in. tubes 14 ft. 6 in. long, the outboard condensers representing a cooling surface of 9,600 sq. ft., with ¾ in. tubes 11 ft. 6 in. long. The tubes are of



Diesel engine driven auxiliaries with generators.

special "A. E." super-nickel non-corrodible steel supplied by Allen Everitt & Sons, Ltd. Incidentally, if may be stated that the vessel contains about 60 tons of steel condenser tubes and ferrules, with a total length of 61 miles of tubing.

The main electrical generating plant for lighting and other use consists of four Diesel engine driven generators, each of 450 kw., located in their own engine room, and two steam turbo-generators, each of 800 kw. in the forward engine room, these latter having been supplied by the British-Thomson-Houston Co., Ltd., of Rugby. Also the Diesel engines, each developing 660 hp., were built by the Fiat British Auxiliaries Ltd., of London, being of the 4-cylinder air injection type with cylinders of 400 mm. bore and 500 mm. stroke, running at 260 r.p.m., giving a mean piston speed of 850 ft. per min., and having a very ample overload capacity. Each engine is direct-coupled to its generator.



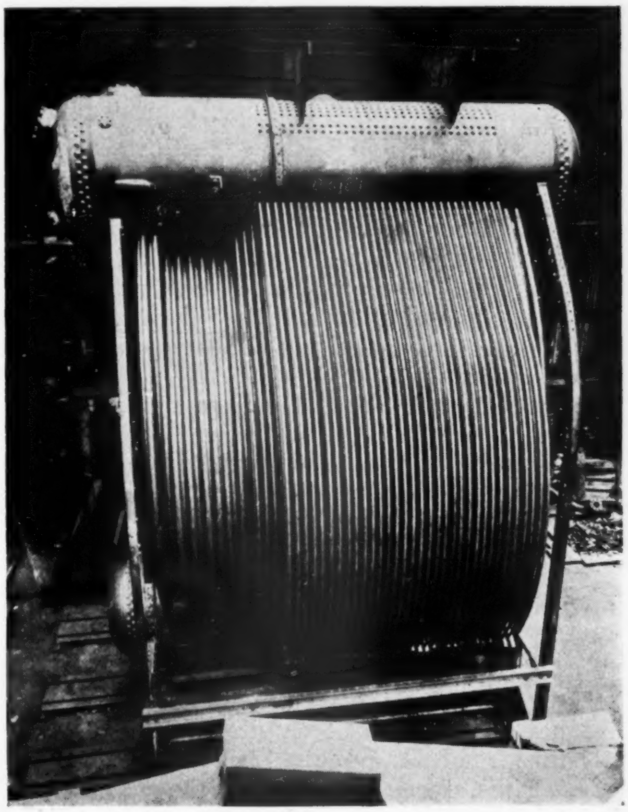
Johnson boiler as completed.

As regards the steam generation plant the general principle is a development of that adopted by Mr. Johnson in the Duchess class of Canadian Pacific steamships, as well as for the Empress of Japan, being high pressure water tube boilers for main running and auxiliary lower pressure Scotch boilers for the make-up feed, ship's heating, and general incidental work.

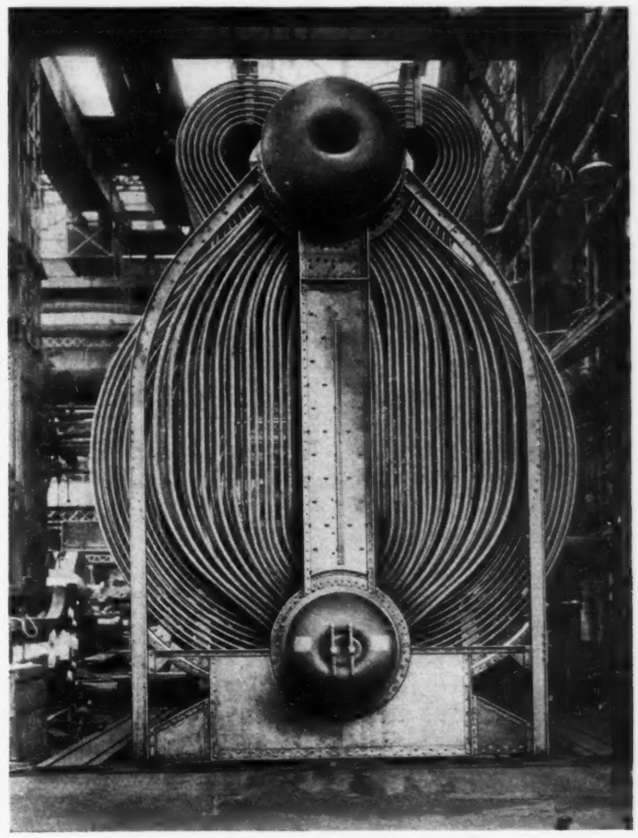
The main boiler plant of the Empress of Britain consists of 8 Yarrow water tube boilers and 1 Johnson water tube boiler, all made by John Brown & Co., Ltd., to the designs respectively of Yarrow & Co., Ltd., of Scotstoun (Glasgow) and Canadian Pacific Steamships Ltd. The firing is by means of oil, under conditions of combined forced and induced draft and air preheaters, the working con-

ditions being 425 lb. per sq. in. and 725 deg. fahr. superheated steam temperature. Also the boilers are arranged in two compartments, six units supplying the two inboard steam 21,000 hp. turbines while the other three boilers supply the outboard 10,500 hp. turbines, although the steam pipes are interconnected. The vessel has three funnels, one of which however, is a dummy, used for ventilating purposes.

The Yarrow boilers are of the well known double-flow, side-fired type with one steam drum, three water drums, and one superheater drum, together with Yarrow superheaters and air preheaters. Both the boiler and superheater drums are made from hollow rolled forgings with the ends formed integrally and without longitudinal or circumferential seams or joints, on the latest high-pressure principles. Each of the boilers has a heating surface of 12,444 sq. ft. with 6,577 sq. ft. in the superheater and 14,629 sq. ft. in the air preheater, while the combustion chamber contains 2,685 cu. ft. Altogether the steam generation plant has 125 tons of superheater tubing of a total length of 184,000 ft. There are seven oil burners of the Wallsend-Howden type, per boiler.



Johnson boiler showing the details of the construction.



Front view of the Johnson boiler with the casing removed.

The Johnson type boiler was first used on the Canadian Pacific coasting vessel Princess Helene, and the results were so satisfactory that it was decided to install one boiler on the Empress of Britain, now of course the crack liner of the company.

This boiler, intended for oil or pulverized fuel firing, consists of a large diameter top and smaller bottom drum vertically one above the other, connected by three tiers of water tubes, both longitudinally and across the ends, the two outer of which are sharply curved and the inner only slightly curved, being almost straight, so as to form a combustion chamber composed entirely of water cooled tubes without any refractory material. Further, there is a water tube wall along the center which divides the combustion chamber into two portions, giving an enormous area for the absorption of radiant heat, while the superheater tubes are interspaced between the boiler tubes, the upper end of the former being extended into the top of the steam drum. The hot combustion gases, after leaving the boiler, pass through air heaters of the tubular type, the arrangement being that the trunks from the air heaters are arranged to enclose the boiler casings to a considerable degree so as to reduce radiation losses, which in fact are negligible in amount because of the efficient system of lagging of the air heaters, heated air passages, and boiler casings.

The unit fitted on the Empress of Britain has a normal evaporation of 68,000 lb. per hr., operating as stated at 425 lb. pressure and 725 deg. fahr. superheated steam temperature, with air heater of 23,943 sq. ft. heating surface and superheater of 3840 sq. ft., giving a very high preheated air temperature of about 500 deg. fahr. for the oil firing. Six oil burners are installed in the combustion chamber which contains 1,117 cu. ft.

The entire rights for the Johnson boiler have now been acquired by Clarke Chapman & Co., Ltd.,

(*Continued on page 46*)

The Combustion Characteristics of Wood

WHILE in the comparatively recent past the chief consideration in the use of wood as a fuel often has been the disposal of the wood rather than its utilization, wood fuel today replaces a considerable quantity of coal in the generation of steam. This is particularly true in the case of paper mills, automobile body works, furniture factories and other industries where large quantities of wood waste are produced and power is required.

Wood is composed chiefly of cellulose, a carbohydrate having the formula $C_6H_{10}O_5$, and lignone, a complex compound of similar composition. Ultimate analyses of representative woods are given in the accompanying Table. These analysis are given on a dry basis. Freshly cut wood may contain as high as 50 per cent moisture and even when air dried or seasoned it usually contains from 20 to 25 per cent moisture.

Wood fuel for industrial purposes is usually in the form of saw dust or shavings, though often it is reduced to chips by means of a "hogger." In these forms it can be handled and introduced into the furnace by mechanical means. Bagasse, the spent sugar cane from which the sap has been extracted and leached tan bark are similar in composition to wood and have practically the same burning characteristics. The two latter fuels, however, usually have a higher moisture content.

The furnaces for burning wood refuse are usually of a dutch oven type and, when the fuel contains a high percentage of moisture, are arranged to expose the fuel bed as much as possible to the hot refractory. The wood refuse is fed through the arch on to grates or when the grates are omitted directly on to the hearth below. In the latter case the air is introduced through rows of tuyeres in the furnace walls. As wood refuse has a high volatile matter content, up to 80 per cent, dry basis, it is necessary to provide a considerable quantity of air over the fire in order to insure complete combustion.

Combustion rates of 200 to 300 pounds of wood refuse per square foot of grate or hearth area per hour may be obtained. The dutch oven acts as a gas producer and a large part of the gaseous combustion takes place in the furnace space outside the dutch oven.

The chart on the opposite page shows the composition of the flue gas, the weight of air required and the weight of the products of combustion plotted against excess air. An average wood of the following analysis was assumed:

Carbon	50	per cent
Hydrogen	6	" "
Oxygen	43.5	" "
Ash	.5	" "

The curves for the weight of air required and weights of products of combustion are based on moisture free fuels and must be corrected for moisture. Thus, for a wood containing 40 per cent moisture the air required at 50 per cent excess would be 8.95 x (1.0 — .4) or 5.37 lb. The weight of the total products of combustion would be 9.94 x (1.0 — .4) plus the moisture, .4 lb. The total products of combustion may also be obtained by adding to the amount of air required, the fuel gasified, and equals 5.37 plus (1 — ash).

ANALYSIS OF REPRESENTATIVE WOODS

Ultimate Analysis—dry basis

	Carbon	*Hydrogen*	*Oxygen*	*Nitrogen*	*Ash*	*B.t.u.*
Ash	49.18	6.27	43.91	.07	.57	8500
Beech	49.36	6.01	42.69	.91	1.06	8600
Birch	50.20	6.20	41.62	1.15	.81	8600
Elm	48.99	6.2	44.25	.06	.50	8500
Oak	49.64	5.92	41.16	1.29	1.97	8300
Pine	50.31	6.20	43.08	.04	.37	9000
Bagasse	47.0	5.5	46.0	...	1.5	8300
Tan bark	51.8	6.04	40.74	...	1.42	9500

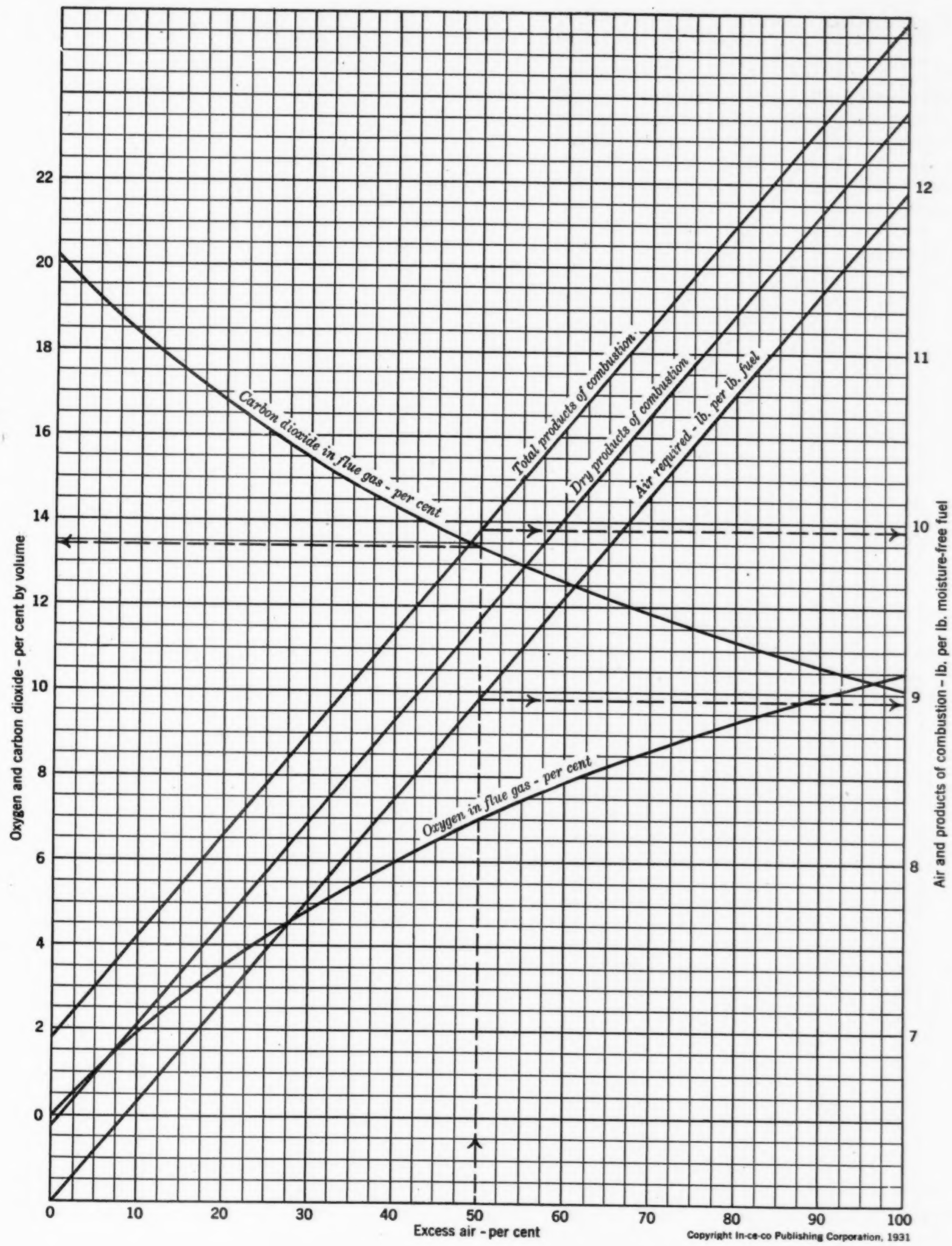


CHART SHOWING COMBUSTION CHARACTERISTICS OF WOOD AND SIMILAR VEGETABLE FUELS

No. 27 of a series of charts for the graphical solution of steam plant problems.

Marine Steam Generation

(*Continued from page 43*)

of Gateshead-on-Tyne, who have let on license the manufacturing rights to Harland and Wolff Ltd. (Belfast), Fairfield Shipbuilding & Engineering Co., Ltd., (Glasgow), Wallsend Slipway & Engineering Co., Ltd., (Wallsend-on-Tyne), William Denny & Brothers Ltd., (Dumbarton), and J. S. White & Co., Ltd., (Cowes) all well known shipbuilding firms.

Each of the nine boilers has two automatic feedwater regulators, one of the Weir contraflo type and the other of the Mumford type.

The air for all the water-tube boilers is supplied by nine forced draft fans, 63 in. diameter, of the Howden double-inlet type, one fan being intended for each boiler, along with an induced draft fan 75 in. diameter, of the Howden single-inlet type, fitted above the air heaters, the uptakes as well as the funnels being sub-divided accordingly. As regards fuel oil pumping and heating, the installation is of the Wallsend-Howden type, manufactured by the Wallsend Slipway & Engineering Co., Ltd., consisting of 9 units, one for each water-tube boiler, comprising Weir vertical pump with automatic oil pressure control valve, horizontal heater, duplex suction strainer, and "Auto-Klean" discharge strainer.

The auxiliary boiler plant consists of two cylindrical Scotch boilers operating at a pressure of 200 lb. per sq. in., situated in the forward boiler room, oil fired with Howden forced draft, comprising two 57 in. diameter fans, and supplying all the ship's heating and other domestic low pressure steam, as well as driving all the auxiliary machinery operated with internal lubrication, no trace of oil in the exhaust steam passing into the high pressure system.

Further, the steam equipment includes Supreme vortex return flow boiler separators or steam dryers, and in addition Tompkins patent tangential steam dryers, operating on the whirling or centrifugal principle, whereby the particles of water in the steam are thrown to the outside by centrifugal force.

A most elaborate equipment of scientific control instruments is provided for the operation of the boiler plant, including Mono CO_2 and CO recorders of the duplex type, supplied by James Gordon & Co., Ltd., of London, corresponding to one instrument for each of the three main boilers, and an equipment of Foster thermo-electric pyrometers by the Foster Instrument Co., of Letchworth. Each of the Yarrow boilers has an indicating pyrometer, with a separate flat reading dial, in the combustion gases before and after the air heater. The Johnson boiler, however, which is to be tested in the most elaborate manner, is provided with a Foster recording thermo-electric pyrometer on the "strip" principle to give a continuous record of the temperatures at a number of different points in the setting. These pyrometers are equipped with the firm's patent "Resilia" spring mounted pivot and jewel device for the moving coil, so that they are not affected by vibration, even that of a fast turbine vessel, which has a peculiar motion of small amplitude and high periodicity.

Little information has yet been made available concerning the results being obtained by the Empress of Britain as Canadian Pacific Steamships, Ltd., prefer to wait until a number of voyages have been made. It is stated unofficially, however, that 88 per cent steam generation efficiency is being obtained, along with 0.57 lb. of oil per shaft hp. This is a world's record for a vessel in regular commercial use, and a considerable improvement on the figures of the Empress of Japan averaging from 0.603 to 0.625 lb. oil per shaft hp. which at the time was regarded as very advanced performance.

As regards the Johnson boiler, the main advantages claimed are light weight, high rate of circulation and evaporation, great flexibility and reduction in wear and tear and maintenance costs because of the elimination of brickwork. The total weight of the boiler on the Empress of Britain including the air heater, is 166 tons, whereas the weight of a Yarrow unit for a slightly smaller output is 244 tons, and it is stated double the steam output is obtained as compared with an ordinary 3-drum type of marine water tube boiler for equal weight and air heater capacity.

Selsyn Devices and Their Applications

(*Continued from page 39*)

measured by two flow meters equipped with Selsyn transmitters.

Selsyn transmission is very accurate and may be accomplished by the use of comparatively small connecting wiring, the limitation being that the resistance per lead should not exceed 35 ohms for the average installation. When the same power source is available at both the locations of the transmitter and receiver, it is only necessary to run three connecting wires for the stator connections and by providing the required filtercircuit and necessary insulation as well as by taking proper precautions to prevent noise interference, it is entirely practical to use conductors in the same cable with those used for telephone communication. The current and voltage limitations, however, are such that it is not practical to transmit over wires in a telephone cable when Selsyns of the larger designs are employed. The power consumption is very small, being only approximately 6 to 9 watts for the Selsyns normally used in instrument design. They require very little attention since the design provides for continuous operation and automatic reset in agreement with the transmitter upon resumption of power following a power failure. The devices, therefore, are very economical and are well suited to many applications encountered in practically all power stations and industrial plants.

NEWS

Pertinent Items of Men and Affairs

Coal and Coke Research Activities of A. S. T. M. Committee

The American Society for Testing Materials Committee on Coal and Coke, through the Secretary, W. A. Selvig, Chemist, U. S. Bureau of Mines, Pittsburgh, has summarized the activities of the committee for the coming year.

Agglutinating Test for Coal—Laboratory work will be continued investigating the effect of various factors on the agglutinating value test for coal with a view of standardizing a test procedure. The test is intended to give information regarding coking and caking properties of coals. The experimental work is to be conducted at the Pittsburgh station of the U. S. Bureau of Mines with the aid of a Carnegie Institute of Technology fellowship supported by the National Coal Association.

Pulverizing Characteristics of Coal—Progress has been made in a laboratory method of test for determination of pulverizing characteristics of coal in connection with the commercial pulverization of coal for use as powdered fuel. It is probable that arrangements can be made for investigating this problem by the Battelle Memorial Institute and by the Seattle station of the U. S. Bureau of Mines. Considerable experimental data has already been obtained through experiments conducted by the laboratory of the Combustion Engineering Corporation.

Coke Sampling—The subcommittee on coke sampling plans to develop a method for sampling of coke for analysis. Such a method will give directions for collecting gross samples of coke and reducing them to a convenient quantity for transmittal to the laboratory. It is intended that the method shall be similar in principle to the present standard method for sampling coal except for modifications based on the differences between coal and coke. Coke is usually more uniform in composition than is coal, so smaller gross samples should be allowable in case of coke.

Nomenclature and Definitions—The Committee has undertaken the preparation of definitions of the terms "net calorific value" and "gross calorific value." The "gross calorific value" is that obtained in bomb calorimeters and this differs from "net calorific values" which are obtained when coal is burned in use. The "net calorific values" are especially important in comparing heating values of solid and liquid fuels.

Foundry Coke Specifications—The consideration of new or revised specifications for foundry coke will be continued.

Third International Conference on Bituminous Coal

One of the most interesting sections of the Third International Conference on Bituminous Coal, which will be held at the Carnegie Institute of Technology, Pittsburgh, November 16 to 21, will be devoted to a study of fuels in locomotives and steamships. Pulverized coal will receive major attention in the discussions in this section.

While American engineers have not met with highly satisfactory results in their experimentation with pulverized coal in locomotives, German scientists are going forward with the work and have reported progress.

Other subjects to be discussed in the sectional meetings of the conference are cleaning and preparation, hydrogenation of coal, fertilizer, low and high temperature distillation, gasification of coal, combustion, smoke abatement, origin and classification of coal, and the competition between coal and natural gas, petroleum, and water power.

•

The Reliance Gauge Column Company, Cleveland, Ohio, has purchased the safety water column, water gauge, gauge cock, and gauge glass illuminator business of the Roberts Steam Specialty Co., and The Cleveland Flue Cleaner Mfg. Co., both of Cleveland. Some of these newly acquired products possess considerable merit, and all are being put through the Reliance Engineering Department for further improvements and consolidation with the Reliance line.

•

The Peabody Engineering Corporation, New York City, manufacturer of oil and gas burners, announces the appointment of the H. W. Kaiser Company, 1836 Euclid Avenue, Cleveland, Ohio, as its representative in Northern Ohio.

•

The Ellison Draft Gage Company, Chicago, Ill., has appointed the Smiley Equipment Company, 102 Carmen's Building, Kansas City, Missouri, as exclusive representative in eastern Kansas and western Missouri. The Power Equipment Company, 5473 Delmar Blvd., St. Louis, Mo., has been made exclusive representative in the eastern Missouri territory.

•

B. F. Sturtevant Company, Hyde Park, Boston, Mass., has announced the following changes in sales personnel: Walter L. Hunken has been appointed manager of the company's Greensboro, N. C., office; E. A. Engdahl has been appointed manager of the Seattle office; and Philip Cohen has been made acting manager of the Cleveland office.

•

Laclede Christy Clay Products Company, St. Louis, Mo., has announced the purchase of all of the assets of the Buckeye Clay Products Company, Toledo, Ohio, and the Walsh Clay Products Co., St. Louis.

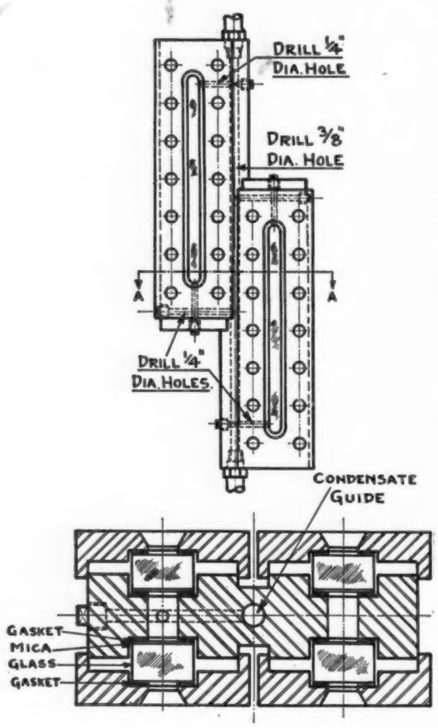
NEW EQUIPMENT

of interest to steam plant Engineers

Flat Glass Steel Gage Insert

The Yarnell-Waring Company, Chestnut Hill, Philadelphia, has introduced a new design of flat glass gage for high pressure boiler service The new gage is available in two designs—the two glass type and the four glass type. The four glass design is shown in the accompanying illustrations.

One of the most important items of construction of these YARWAY Inserts is an improved condensate guide which



consists of a channel of circular cross section, drilled through the insert body, parallel to and connected with the glass chamber. This channel or guide provides for a free and unobstructed flow of condensate. The top and bottom gage connections discharge directly into the condensate guide, thus causing all of the condensate to run down the guide instead of down the glass.

The clouding and erosion of glasses and mica in flat glass inserts is caused by the impinging and solvent action of the condensate. Mica is used to protect the glass from this attack, but mica of sufficient thickness to resist the continual wash of hot condensate reduces the visibility or ease of reading the water level. Since this condensate guide eliminates this discharge against the glass, much thinner mica can be used, thereby allowing a greater amount of light to pass through the insert. The water level can be observed with greater clarity and the life of the glass and mica protection faces is very much lengthened.

YARWAY Water Gage Steel Inserts are machined from solid rolled steel bars. This eliminates all chance weaknesses and imperfections to which castings are subject. The gage valves are of forged steel, monel trimmed with renewable seats. The studs are all of class "C" bolting material. Furthermore, these inserts are rust proofed by means of sherardizing. This protects them inside and out from rusting and forming deposits on the glass.

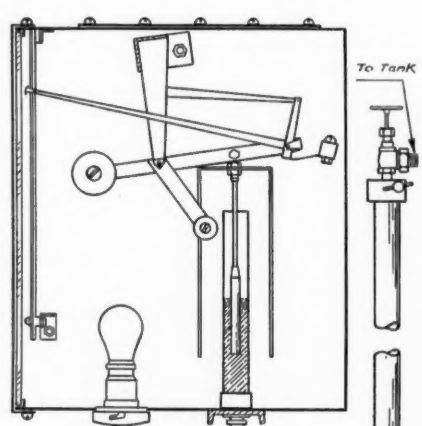
The glass is of the highest quality, especially selected, ground, polished and tempered. It has a very high strength factor, unusual clarity, and complete interchangeability. It is installed between two asbestos gaskets each 3/32 in. thick, that are suitable for high temperature steam conditions.

New Liquid Level Gage

The Ellison Draft Gage Company, Chicago, Ill., has developed a liquid level gage for elevated tanks vented to the atmosphere. A mercury U-column is used to measure directly the liquid head or static pressure corresponding to varying liquid levels in the tank, balancing an equivalent column of mercury against the liquid head obtaining.

One leg of the U column terminates in an indicating pointer gage having mechanism known as the Ellison Straight-Line Movement, and as used in Ellison Pointer Draft Gages. When the liquid pressure is exerted on the mercury column, the mercury is depressed in the reservoir, rises through the small tubing and flows into a well in the gage.

The movement of the mercury in the well actuates a plunger attached to the beam. The pointer gives a true indication of the liquid level over the entire range of a straight-line scale of uniform spacings. Scales read either directly in feet or in fractional levels between full and empty tank as specified.



The mercury column is furnished with a needle valve for 1/8 in. connection to tank, vent and drain. The column is designed so as to require only about 5 pounds of mercury, depending upon range and head to be measured.

The gage is illuminated from the interior and may be mounted on a panel, flush or semi-flush, or on a wall with either vertical or tilted scales to obtain best visibility. The gage can also be furnished in multiple units for two or more tanks with the pointer movement in a common case and a compact header arrangement of the mercury columns.

Combustion Ratio Meter

A recent development of the Bailey Meter Company, Cleveland, Ohio, is the Bailey Ratio Meter for use as a combustion guide in the firing of gas or oil fired heaters, kilns, and all types of industrial furnaces.

The primary purpose of this new Ratio Meter is to provide furnace operators

with an easily understandable guide which will enable them to maintain a definite relation between the amounts of air and fuel supplied to the furnace so as to obtain high combustion efficiency. This is accomplished by an ingenious method. Referring to the accompanying illustration, it will be noted that the meter contains two recording pens. One records the rate of oil flow and is actuated by a simple mechanical type of mechanism which receives its motive power from the differential pressure produced by an orifice in the fuel line. In similar manner, the shorter pen records the flow of air to the furnace. At the time the meter is being installed, a complete combustion test is run on the furnace to determine what ratio between air flow and fuel flow corresponds to best combustion conditions, and the air flow mechanism is then adjusted so that this ratio is always obtained when the two records coincide, one upon the other. The furnace operator, therefore, merely has to keep the two pens together by proper manipulation of the air supply to be assured that maximum economy is being secured.

In addition to serving as a combustion guide, the Ratio Meter is valuable as a fluid meter on the fuel line.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Blast Gates

General Electric Blast Gates for low pressure air and gas systems are presented in a new folder. These gates are offered to fulfill the exacting requirements of blower service. Careful design and workmanship insure minimum leakage, close regulation and positive operation. Various types of construction are available, including simple hand-operated gates, semi-automatic, self-closing gates, and motor-operated gates, which are adapted to full automatic control. 4 pages, 8½ x 11—General Electric Co., Schenectady, N. Y.

Boiler Surface Protection

A new folder describes the application and advantages of Apexior Protective Coating which, with brush applied to the internal boiler surfaces, forms a thin, smooth, impenetrable barrier, chemically inert, between the water and the boiler steel. Apexior Coating, backed up by proper feedwater treatment, insures a protection against deterioration of the boiler steel by steam and water. 4 pages, 8½ x 11—The Dampney Company of America, Hyde Park, Boston, Mass.

Furnace Construction

The Esenco Combustion System provides a refractory interlocking furnace wall construction which is ventilated and air admitting. The construction provides for admitting pre-heated secondary air where it is most vitally needed—immediately over the coking section of the fire where the volatiles are being distilled, or under the dump section of the stoker as a means of burning out the combustible in the ash. An alternate construction embodying the use of water-cooled walls is also offered. 6 pages, 8½ x 11—Essex Engineering Company, Belleville, N. J.

High Temperature Mortars

"High Temperature Mortars & Plastic Chrome Ore" is the title of a new booklet describing general refractories. Several types of high temperature mortars are presented, including Grefco, a dry chrome base mortar with a fusion point of over 3400 deg. fahr.; Briklok-A, a plastic mortar for temperatures up to 2900 deg. fahr. and applicable for either troweled joints or for patching and repair work. 16 pages, 3½ x 6¼—General Refractories Company, 106 South 16th St., Philadelphia, Pa.

Industrial Instruments

New Bulletin No. 174 is a general catalog describing the Foxboro line of industrial instruments for controlling, recording and indicating temperature, pressure, humidity and flow. The catalog is profusely illustrated to show details of the various instruments and their application to a wide range of industrial uses. An interesting double-page spread in color emphasizes the salient features of Foxboro recording instruments. 32 pages and cover, 8½x11—The Foxboro Co., Foxboro, Mass.

Instruments and Meters

The complete line of TAG instruments for indicating, recording and controlling temperature and pressure in industrial processes is presented in a new general catalog No. 1000. Appropriate classifications of the many groups of instruments have been provided, and suggested applications are accurately described and illustrated. This catalog is a veritable reference library of industrial instruments and their application, and will be of definite value to engineers and plant executives. 100 pages and cover, 8½ x 11—C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.

Oil Burner Ignition

A new bulletin describes General Electric Ignition Transformers for oil burners. Two types of transformers are offered, one for direct oil ignition and the other for gas electric ignition, in which the transformer is used to ignite a gas pilot, which in turn ignites the oil fuel. Tables of dimensions and capacities are included, together with complete descriptions and illustrations of the various types of transformers available. 8 pages and cover, 8½ x 11—General Electric Company, Schenectady, N. Y.

Plastic Heat Insulation

A new bulletin presents STIC-TITE, an efficient heat insulation material composed of light mineral fibre which when mixed with water forms an extremely adhesive plastic cement. This material will withstand temperatures up to 2000 deg. fahr. and possesses many unique advantages. The bulletin illustrates many typical applications of this material, and charts and tables are included to assist in calculating the savings made possible by this plastic heat insulation. 16 pages and cover, 8½ x 11—Refractory & Engineering Corporation, 50 Church Street, New York.

Potentiometer Pyrometer

An attractive folder "Bringing Laboratory Accuracy to Industries" shows in tabloid form the principal features of the new Brown Potentiometer. Extreme accuracy and ruggedness is claimed for this new instrument, and the folder shows many of the structural features to substantiate this claim. The folder is arranged for easy reading and presents a clear idea of this new instrument. 12 pages, 3½ x 8¾—The Brown Instrument Company, Wayne and Roberts Avenues, Philadelphia, Pa.

Small Stoker Unit

A new folder describes the C-E Stoker Unit, a self-contained underfeed stoker with electrical drive and integral fan construction. This stoker provides a simple and reliable automatic machine for firing small boilers, up to 200 hp. This stoker has a number of features not available in other machines of this size, such as agitated grate bars, side dumping grates and agitated feed hopper which eliminates arching of the coal and interrupted feed. The design is self-contained, completely enclosed and provides a simple, rugged and dependable unit for the underfeeding of coal under small boilers. Five sizes are available with coal burning capacities of 150 lb., 300 lb., 600 lb., 1000 lb. and 1500 lb. of coal per hour respectively. 4 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

Steam Jet Conveyor

Hahn Steam Jet Conveyors for ashes soot, slag, coke and other abrasive materials are described in new Bulletin No. 11. The simplicity of these conveyors is emphasized by several application illustrations, and the details of construction and operating principles are shown by line drawings. 6 pages—8½ x 11—Hahn Engineering Company, 30 Church Street, New York, N. Y.

Welded Boiler Drums

To meet the insistent demand for literature pertaining to welded boiler drums, the technical article "Tests of Welded Boiler Drums," by A. J. Moses has been reprinted from COMBUSTION magazine, and is now available for distribution. This technical article is replete with data pertaining to an exhaustive series of tests conducted at the Chattanooga plant of the Hedges-Walsh-Weidner Co. on fusion welded drums. This article is recognized as an up-to-the-minute and authoritative discussion of the important subject of fusion welded boiler drums. 8 pages and cover, 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 Madison Ave., New York

Boiler, Stoker and Pulverized Fuel Equipment Sales

BOILER SALES

Orders for 820 boilers were placed in June according to reports submitted to the Bureau of the Census by 73 manufacturers.

Month	1930 Number	1930 Square feet	1931 Number	1931 Square feet
January	942	1,081,749	598	576,723
February	873	938,906	516	622,343
March	977	1,263,709	630	664,784
April	1,017	1,070,093	689	825,203
May	1,283	1,329,748	658*	603,401*
June	1,360	1,588,553	820	678,859
Total (6 mo.)	6,452	7,272,758	3,911	3,971,313
July	1,309	1,410,096		
August	1,371	1,356,751		
September	1,254	1,282,388		
October	1,189	851,525		
November	777	709,322		
December	814	587,053		
Total (Year)	13,166	13,469.893		

* Revised.

TOTALS FOR FIRST 6 MONTHS AND NEW ORDERS, BY KIND, PLACED IN JUNE, 1930-1931

Kind	1930 No.	1930 Sq. ft.	1931 No.	1931 Sq. ft.	June, 1931 No.	June, 1931 Sq. ft.
Stationary:						
Total	6,452	7,272,758	3,911	3,971,313	820	678,859
Water tube	611	3,229,444	362	1,639,352	88	308,360
Horizontal return tubular	479	660,093	255	318,070	57	77,751
Vertical fire tube	643	204,139	330	87,955	55	12,197
Locomotive, not railway	107	91,603	59	54,969	11	9,224
Steel heating	3,554	1,607,912	2,361	1,085,834	535	206,716
Oil country	583	670,345	245	275,241	30	34,845
Self contained portable	262	183,451	145	92,729	24	17,262
Miscellaneous	81	50,962	36	21,111	8	3,419

MECHANICAL STOKER SALES

June stoker sales, reported to the Bureau of the Census by the 11 leading manufacturers, totaled 111 stokers of 29,889 hp.

Year and Month	TOTAL No.	TOTAL H.P.	INSTALLED UNDER Fire-tube boilers No.	Fire-tube boilers H.P.	Water-tube boilers No.	Water-tube boilers H.P.
1929						
Total (First 6 mo.)	812	293,221	291	45,919	521	247,302
Total (Year)	1,716	599,585	706	102,515	1,010	497,070
1930						
January	53	13,198	24	2,872	29	10,326
February	73	22,648	26	3,732	47	18,916
March	89	32,403	45	6,128	44	26,275
April	108	35,903	46	6,984	62	28,919
May	96	31,956	41	5,703	55	26,253
June	151	47,803	70	10,100	81	37,703
Total (6 mo.)	570	183,911	252	35,519	318	148,392
July	150	37,761	83	11,434	67	26,327
August	115	29,988	61	10,587	54	19,401
September	128	42,899	71	9,186	57	33,713
October	92	38,276	46	5,148	46	33,128
November	71	21,103	41	5,731	30	15,372
December	53	11,726	35	5,307	18	6,419
Total (Year)	1,179	365,664	589	82,912	590	282,752
1931						
January	85	25,902	40	6,719	45	19,183
February	67	14,249	37	5,326	30	8,923
March	63	17,993	27	4,509	36	13,484
April	65	18,723	32	5,192	33	13,531
May	80	23,646	29	4,341	51	19,305
June	111	29,889	55	8,519	56	21,370
Total (6 mo.)	470	130,002	220	34,606	250	95,396

PULVERIZED FUEL EQUIPMENT SALES

June orders for coal pulverizers as reported to the Bureau of the Census aggregated 21 pulverizers having a total capacity of 66,160 lb.

Year and Month	STORAGE SYSTEM — PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent	DIRECT FIRED OR UNIT SYSTEM — PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS														
1931														
January	2	2	..	60,000	1	51,177	704,000	8	4	4	40,500	9	42,970	412,675
February	1	..	1	40,000	1	29,100	375,000	2	2	..	8,000	1	7,570	75,000
March	2	2	..	60,000	..	.....	......	13	13	..	122,000	8	93,960	1,404,000
April	2	2	..	60,000	1	34,300	592,000	9	8	1	49,250	6	46,300	538,200
May	..	..	..	.....	..	.....	......	..	..	..	.....	..	.....	......
June	..	..	..	.....	..	.....	......	14	6	8	59,360	11	56,080	530,290
Total (6 mo.)	7	6	1	220,000	3	114,577	1,671,000	46	33	13	279,110	35	246,880	2,960,165
FOR INSTALLATION UNDER FIRE-TUBE BOILERS														
1931														
January	..	..	..	.....	..	.....	......	6	..	6	6,000	6	7,500	53,350
February	..	..	..	.....	..	.....	......	3	..	3	2,250	3	3,000	22,350
March	..	..	..	.....	..	.....	......	2	1	1	2,750	1	3,004	22,500
April	..	..	..	.....	..	.....	......	1	..	1	4,000	2	6,700	45,000
May	..	..	..	.....	..	.....	......	3	1	2	3,800	3	6,000	27,000
June	..	..	..	.....	..	.....	......	4	1	3	4,000	4	5,750	22,100
Total (6 mo.)	..	..	..	.....	..	.....	......	19	3	16	22,800	19	31,954	192,300


"Boilers as clean as day installed"
says the Plant Engineer where the Cochrane Hot Process Softener here shown treats the boiler feed water. The old boiler house at the same plant has a zeolite softener and the Plant Engineer at first thought the Consulting Engineers had made a mistake in changing over to the Hot Process Softener for the new plant, but he is now convinced that the HOT PROCESS IS BEST FOR BOILERS, which judgment is confirmed by that of all engineers who have had experience with Cochrane Softeners.
Names upon request. Also ask for treatise on "Hot Lime-Soda-Phosphate Treatment of Feed Water for High Pressure Boilers."
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BOOKS

1 DRAFT AND CAPACITY OF CHIMNEYS

By J. G. Mingle

339 Pages. Illustrated — Price $3.50

The most authoritative book ever published on the subject of draft and chimneys. The subject matter has been developed primarily from a theoretical standpoint and then amplified by experimental data gleaned from actual practice.

The author observes that draft, even to the expert, frequently contains an element of mystery, and that there is often a great deal of confusion and misconception on the subject. A careful study of this book will give a thorough and practical knowledge of this important subject.

The book is profusely illustrated with graphs and charts. Many valuable tables are included and the index has been prepared for ready reference.

2 MODERN COMBUSTION, COAL ECONOMICS AND FUEL FALLACIES

By C. V. Beck

380 Pages — Price $3.00

This book was reviewed in the August issue of COMBUSTION and judging by the response created widespread interest. The author, a coal man of long experience, writes interestingly and authoritatively on all phases of coal, its production, preparation and utilization. He has devoted chapters to modern combustion, including much information and data of interest to operating engineers as well as to executives. The book emphasizes the necessity for present day merchandising, recognizing the competition of other fuels. It is extremely readable.

3 HEAT POWER

By E. B. Norris and E. Therkelsen

Price $3.50 — 376 Pages

This book is thoroughly up-to-date. The first part of the book covers internal combustion engines of all types. The second part pertains to various types of steam engines, steam turbines, condensing equipment, steam boilers, boiler fuels and furnaces, and boiler performance. The section devoted to steam plant equipment contains illustrations and descriptions of the most modern stoker and pulverized fuel furnace and boiler arrangements.

4 DIESEL ENGINE OPERATION, MAINTENANCE AND REPAIR

By Charles H. Bushnell

285 Pages — Price $3.50

The author has written this book from the viewpoint of the operating engineer and treats of the fundamental principles rather than the details of design which are constantly changing. The first part of the book is devoted to internal combustion engine cycles, thermodynamics, combustion and fuel. Further chapters cover vaporizing, mixing and ignition systems, and mechanical fuel injection. The balance of the book discusses the principal parts and elements of Diesel engines and covers such subjects as engine nomenclature, rating, lubrication, knocks, operation and maintenance. An Appendix entitled "Conversion Tables and Equivalents" contains reference tables and other valuable data.

5 BOILER FEED WATER PURIFICATION

By S. T. Powell

363 Pages — Price $4.00

A presentation of such basic facts concerning feed water treatment as may assist the designing engineer in the selection of the appropriate type of treatment and may aid the operating engineer in controlling the system most efficiently.

6 A HANDBOOK OF ENGLISH IN ENGINEERING USE

By A. C. Howell

308 Pages — Price $2.50

Here is a real up-to-the-minute handbook that should be on the desk of every technical writer. Most engineers today have occasion to do considerable writing and for those who have some doubt as to their ability to express themselves clearly, accurately and in acceptable form, Professor Howell's book will be of very definite value. The author takes a very practical point with regard to the engineer's professional use of language. Chapters are devoted to word usage and idioms, sentence and paragraph structure, composition, punctuation and the mechanics of writing and grammar. Examples cover letters, reports and technical articles.

7 POWER PLANT LUBRICATION

By W. F. Osborne

Price $3.00 — 275 Pages

A practical book for the power plant engineer explaining the physical and chemical properties of lubricants, their action under changing influence of heat, pressure, etc., and the methods of determining their relative values. The book shows the practical application of lubricants to the principal types of power plant machinery and gives specifications and standard tests.

Enclosed find check for $.......... for which please send me the books listed by number.

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Books Nos. ....

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General Electric Introduces Line of Electric Steam Generators

THE General Electric Company announces a line of electric steam generators for application anywhere in industry where steam is needed but is not available in sufficient quantities or at suitable pressure. The line includes two pressure ratings—100 and 200 pounds—in various sizes and ratings.

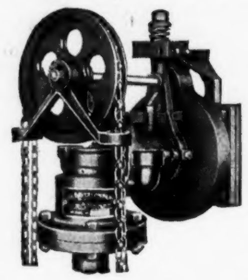
The standard unit consists of a suitable steel container in which one or more helicoil sheath-wire immersion heaters (depending upon the capacity required) are inserted. The generator is provided with standard boiler fittings, including a safety valve, steam gage, water column, blow valve, steam valve, etc. A typical control equipment consists of a magnetic switch and an automatic pressure governor which, when operated in conjunction with a low-water alarm, automatic heat-shut-off switch and some device for automatically feeding additional water to the generator, makes the equipment completely automatic.

Strictly speaking, the normal rating of an electric steam generator is its maximum rating, but additional capacity (in pounds of steam that can be "flashed" for a given interval) can be obtained by incorporating in the design an accumulator capacity. This is attained by raising a larger volume of water to a higher pressure than for normal requirements and providing the electric steam generator with a pressure reducer.

Many applications are listed for this equipment by the manufacturer, including: atomizing oil for oil burners, cavity vulcanizers (tires), coil-forming presses, core vulcanizers (tires), dish washers, dry cleaners' hat tables, gluepots, heat treating aluminum castings, Hoffman pressing machines, hot water tanks, impregnating tanks, ovens, plate-bending rolls, steam heat, electric furnaces for bright annealing copper, humidifiers for air conditioning, automobile washing machines, evaporating plants, laboratory steam generators, etc.

The units are available with generator shells of numerous different standard sizes. Several different kilowatt input ratings are obtainable for any given generator. Three-heat switches can be furnished for each 5-kilowatt heater unit up to a rating of 15 kilowatts so that a variety of ratings may be obtained from 1.25 kilowatts to 15 kilowatts by increments of 1.25 kilowatts. The units are designed to operate on 115, 230 or 440 volts direct or alternating current.

Advantages as listed by the manufacturer include the following: no stacks or flues required; completely automatic operation, low maintenance; quick heating—usually much faster than a fuel-fired boiler; no fuel storage or space for same required; no ashes to be removed, compact—can be mounted on ceiling, side wall or floor; very accurate temperature control—within 2 or 3 deg. fahr.; steady load at unity power-factor, and units meet specifications of A.S.M.E. boiler-construction code.

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